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Analysis of surgical processes

Central Operating Theatre from Centro Hospitalar Lisboa-Norte

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Abstract

In the Portuguese Health System, hospitals are critical organizations whose performance should be focused in a continuous improvement to guarantee the patient's needs. In this set Central Operating Theatres (COTs) are of most importance to the hospitals since these units have high impact on costs, revenues and on the other services provided by the organization. These aspects associated with large surgical waiting lists lead to the concern of enhancing the provided service by improving efficiency across all operations.

With this, COT of Centro Hospitalar Lisboa-Norte is used in this project's case study. The identification of the problem under study begins with the presentation of the unit – e.g. processes. With this, it is possible to identify a problem of inefficiency which is the focus of this work.

In this context, a literature review is performed considering Healthcare inefficiencies' causes and solutions, methodologies and techniques in healthcare, Operating Room (OR) indicators and stakeholders. All these aspects aim to provide a baseline to the applied methodology.

The methodology is composed by several steps which intends to provide understanding, solutions development and implementation of the accessed solutions. Considering this, the methodology combines Lean methodologies and Business Process Redesign.

The perioperative process of COT is mapped and described, including the required resources. With this, the flaw points within the process were qualitatively accessed and solutions proposed. In addition, two solutions are developed: intraoperative indicators to evaluate the system and the tool for OR scheduling and material planning.

Keywords: Central Operating Theater, Perioperative Process, Inefficiency, Lean, Business Process Redesign, Intraoperative indicators.

Resumo

No Sistema de Saúde Português, os hospitais são organizações críticas, cuja performance deve considerar a melhoria contínua para garantir as necessidades dos pacientes. Em particular, os Blocos Operatórios são de grande importância para os hospitais pois têm um grande impacto nos custos e receitas, e ainda no fluxo de trabalho de outros serviços no hospital. Estes aspetos, associados a elevadas listas de espera, levam à preocupação de intensificar o serviço prestado através da melhoria da eficiência nas operações.

Com isto, o Bloco Operatório Central (BOC) do Centro Hospitalar Lisboa Norte é usado como caso de estudo. A identificação do problema começa com a apresentação da unidade – ex. processos. Assim, é possível identifica-se um problema de ineficiência que é o foco deste trabalho.

Considerando este contexto, é realizada uma revisão de literatura, que aborda temas como as causas de ineficiências e soluções nos serviços de saúde, técnicas e metodologias utilizadas, indicadores de desempenho e *stakeholders*. Todos estes aspetos constituem uma base de trabalho para a metodologia aplicada.

A metodologia desenvolvida combina as metodologias Lean e *Business Process Redesign*. É ainda composta por vários passos que pretendem proporcionar um conhecimento, desenvolvimento de soluções e implementação das mesmas.

O processo perioperatório do BOC é mapeado e descrito, incluindo os recursos necessários para as suas atividades. Deste modo, os pontos de falha no processo são identificados qualitativamente e são propostas soluções. Foram ainda desenvolvidas duas soluções: indicadores do intraoperatório para avaliação do sistema e *tool* para planeamento da sala operatória e do material.

Palavras-Chave: Bloco Operatório Central, Processo Peri operatório, ineficiência, Lean, Business Process Redesign, indicadores de intraoperatório.

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Índex

Figure Índex

Table Índex

Acronyms List

ASA – American Society of Anesthesiologists;

BPR – Business Process Reengineering;

CHLN – Centro Hospitalar Lisboa-Norte;

COT – Central Operating Theatre;

ECG – electrocardiogram;

HPV – Hospital Pulido Valente;

HSM – Hospital Santa Maria;

IntCU – Intermediary Care Unit;

MGRT - maximum guaranteed response times;

MSS – Master Surgical Schedule;

OR – Operating Room;

OT – Operating Theatre;

PACU – Post-Anesthetic Care Unit;

PM – Process mapping;

SIGIC – Sistema Integrado de Gestão de Inscritos para Cirurgia;

SNS – Sistema Nacional de Saúde (National Healthcare System);

TAC – Computed Axial Tomography;

UCI – Unidade de Cuidados Intensivos (Intensive Care Unit);

VSM – Value Stream Mapping.

1. Introduction

1.1. Motivation

The technological advances and globalization are changing the industries' environment. More differentiation is being built by the existence of more competition within the sectors. One of these sectors is the Healthcare, which is a service industry where the requirements of the patients (consumers) are critical to its development and should be aligned with the organization's objectives [1].

In Portugal the public health sector has its own National Healthcare Plan and National Healthcare Service (*Serviço Nacional de Saúde*, SNS), that aims to provide better and timely healthcare to the Portuguese population. The Portuguese plan is a basic element of healthcare politics in the country, which determines the strategic path of intervention in the Healthcare System. The most recent revision of the National Healthcare Plan (until 2020) aims to obtain gains in healthcare. To do so the goals are to improve the systems performance, as well as the capability of being integrated by fortifying the information systems to decision making, integrating programs and projects, and interventions focused on results. To achieve these goals, an effort is needed to integrate all society's sectors as well as using strategies of citizenry, access and equality, quality and healthy politics [2].

Therewith, hospitals are critical organizations in the system that require deep changes to improve performance. A good performance is not only a high financial capacity but also the efficient use of available resources associated with meeting patient's needs. There are factors that influence the performance management system and when improved help overcome the difficulties that result from low efficiency – management competencies, information sharing and organizational performance [3]. Considering this, specific areas within the hospital may be improved as is the case of the Operating Theatres (OTs).

OTs are critical to healthcare services, mainly to hospitals. The surgical interventions performed, in these OTs, are the major source of admissions into a hospital. This, associated with the large and increasing patient waiting lists [4] as well as the increasing of waiting times [2], lead to the existence of inefficiencies and consequently large expenses [5]. Thus, these facts and the increasing life expectancy [6] (Figure 1), reveals OTs and the respective recovery rooms as critical assets to hospitals [5].

To manage the Portuguese surgical waiting lists, it is used the program *Sistema Integrado de Gestão de Inscritos para Cirurgia* (SIGIC), which aims to manage the registered surgical patients of SNS in an integrated manner. Also, to manage this waiting list, there is a legislated maximum guaranteed response times (MGRT). There is an increase of patients registered in SIGIC's waiting list although the increasing number of performed surgeries, it is still not enough to overcome the increment mentioned before, as seen in Figure 2 [4].

The report of *Avaliação da Situação Nacional dos Blocos Operatórios* [7] shows a large patient waiting list for surgery. In fact, in 2014 the patients of the SNS have a median waiting time of 3 months [7]. In view of this, the improvement of the processes in the operating theatres is critical to fulfill the requirements of SIGIC and reduce the waiting times of the patients, without increasing the available resources and consequently the costs [8].

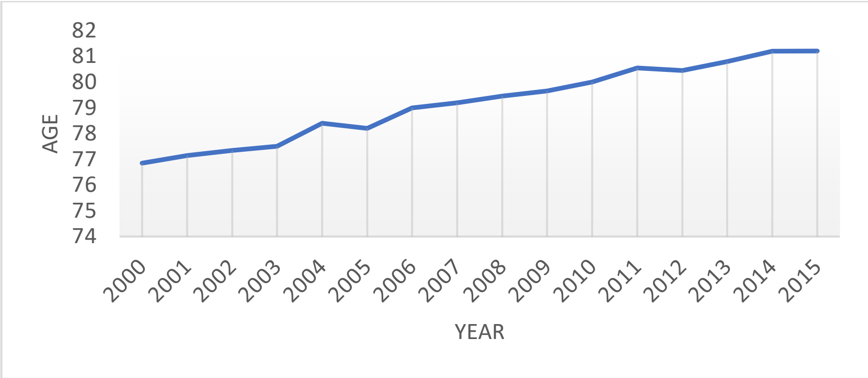

Figure 1: Life Expectancy in Portugal from 2000 to 2015. Source: OECD [6].

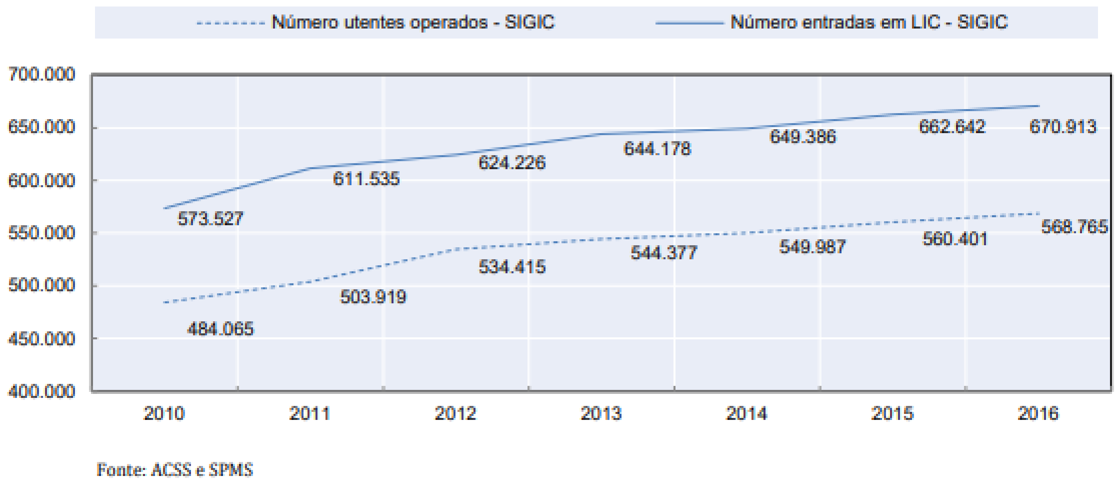

Figure 2: Evolution of the number of patients in the waiting list and performed operations between 2010 and 2016.

Within this context, Centro Hospitalar Lisboa Norte (CHLN) is the case study of this dissertation. CHLN is composed by Hospital Santa Maria (HSM) and Hospital Pulido Valente (HPV) which focus on different surgery types – elective surgery and ambulatory surgery, respectively. According to the report of *Avaliação da Situação Nacional dos Blocos Operatórios* [7], 10% of the patients wait longer than the MGRT. The dissertation addresses inefficiencies in the COT, in HSM, since it performs approximately, 17.3% of the elective surgeries of Lisboa e Vale do Tejo Region [9].

1.2. Objectives and Dissertation' Structure Methodology

The dissertation's aims to: 1) to understand the functioning of the organization's culture and processes, 2) to map the current perioperative process, and 3) to identify the existing flaw points which may lead to inefficiency and propose recommendations to improve the surgical process.

To understand the problem, it is important to be aware of the COT functioning and culture, by exploring the current situation and engage the entities into the project. This comprehension is performed with the inclusion of stakeholders into the development of the dissertation with interviews, visits to the facility and staff follow-up. A literature review in the topic is also performed to provide a baseline to develop the research and problem solving, and to obtain insights of the developed work from other authors and potential problems and solutions that may rise during dissertation's development. Therefore, the dissertation's goals are achieved through the application of a methodology which consists in process mapping and description, the identification of the flaw points through the process, proposed solutions, and the development of the tool for OR scheduling and materials' planning. Therefore, an increasing of the efficiency of the perioperative process is expected as the main objective of this dissertation.

The dissertation is developed in five steps presented in Figure 3 which are forward described.

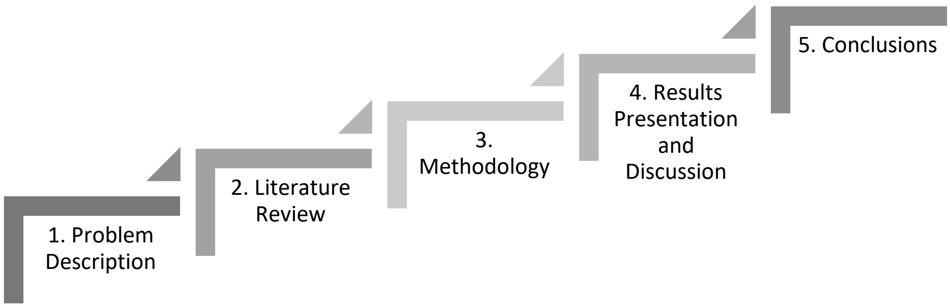

Figure 3: Dissertation structure.

Problem description is performed in step 1. This stage is essential to dissertation's advance due to the need of problem identification. In this sense, a high understanding of the operations within the COT is required just as its characterization. The problem identification is performed considering the current state of the system as well as the objectives to achieve.

In step 2, a literature review is conducted. This addresses the topics considered in the previous step, namely regarding inefficiency causes and solutions, methods and techniques, OR measures and stakeholders. This literature review provides a support basis to the methodology proposal.

The methodology is proposed in step 3. The aim of this step is to identify and describe the suitable methodology applied into the problem solving, which must consider and be supported by the literature review.

Step 4 presents and discusses results. In this step, the process map of the perioperative process is designed and presented as well as the required resources for each process' activity. With the process map combined with interviews with stakeholders and on sight observation, the identification of the flaw points is performed. To finish, solutions are proposed and one of them is developed in detail. During this step, results are discussed and conclusions – step 5 – are stated.

1.3. Outlines

The dissertation is composed by 6 chapters, which are aligned with the dissertation structure and its objectives. A brief description of each chapter is forward presented.

In chapter 1, the context and motivation of this dissertation are presented. The dissertation's structure and objectives are stated as well as a brief description of the dissertation's outlines.

Chapter 2 – Problem Description – provides an understanding of the organization under study. Therefore, a brief description of CHLN and an elaborated description of COT is undertaken. This description includes COT's waiting list, facilities, surgical scheduling, process and resources. In view of this, the problem is integrated into the surgical operational processes of the organization and it is identified as an inefficiency problem.

In chapter 3, a literature review provides a basis for the problem's development and a support to the methodology. The themes addressed in this chapter are process improvement in healthcare, namely the inefficiencies causes and solutions; methodologies and techniques used to identify and overcome inefficiencies; OR measures and stakeholders.

Chapter 4 presents the methodology. In this chapter, a suitable methodology tool is presented with base on the literature review and the problem description. The description of all methodology steps is performed to explain the detailed procedure.

The results provided by the dissertation development are presented and discussed in chapter 5. COT's perioperative process map is presented and described, and the resources required are also presented. With this, several flaw points in the perioperative process are identified and solutions to overcome them are proposed.

Conclusions regarding the developed work are presented in chapter 6. In this chapter, an overview of the dissertation is conducted considering the previous chapters. Future work is also addressed.

The relationship between the dissertation structure (section 1.2) and the outlines (section 1.3) is shown in Figure 4.

Chapter 2 and Problem Description step require a high understanding of the organization – by the description of the case study - and the problem identification. Both chapter 3 and Literature Review step are related with the objective of providing a baseline to the development of the methodology and problem solving. Chapter 4 and the Methodology step are related through the objective which is provide a methodology to be followed in the dissertation. By application of the methodology, it is possible to achieve results and present them in both common to chapter 5 and Results presentation and discussion step. Both have the objective of stating the results achieved and compare them with the existent literature of chapter 3. To finish the dissertation, chapter 6 and Conclusions step state the conclusions of the developed work and feature the future work.

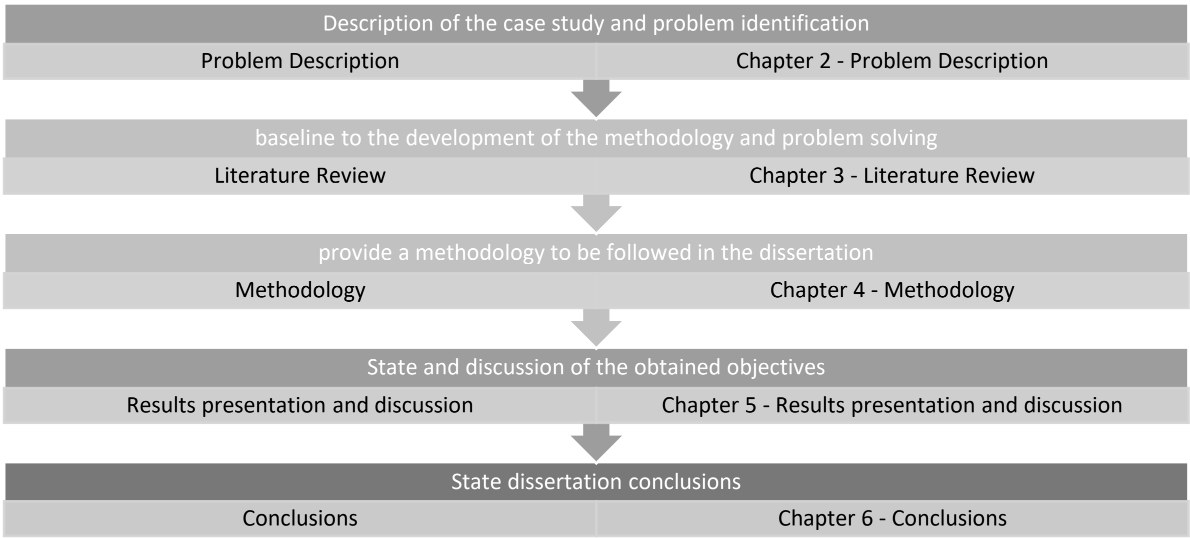

Figure 4: Objectives relating the dissertation's structure (left) and the outlines (right).

1.4. Chapter Conclusions

In this chapter the motivation to develop the dissertation is presented. The large surgery waiting lists and increasing of the patients' requirements into the healthcare industry has been leading to the increasing necessity of service efficiency's improvement. To this end, an integration of the processes and information flow is necessary with focus on surgical operational processes to improve the performance of the system.

Therewith, the dissertation aims to understand the current status of the surgical operational processes in HSM of CHLN as well as identify its flaw points. A base to develop solutions to the problem is provided by the literature review and the methodology. Considering this, a structure to the dissertation is presented which is composed by 6 main steps: Problem Description, Literature Review, Methodology, Results Presentation and Discussion and Conclusions. Each step is briefly described to provide a context to the reader and an initial insight of the dissertation. The outlines of the dissertation are also described in this chapter.

2. Problem Description

This chapter aims to provide a context of the problem under study. To this end, the problem is presented in a generic way – being possible to perform a correspondence with other organizations (section 2.1); then, the organization is described (section 2.2). This description begins by CHLN and goes to the case of HSM's COT and results into a problem identification (section 2.3). The chapter ends in section 2.4, with the main conclusions of the chapter.

2.1. Problem Setting

General OT's operations are standard to all specialties and may be defined by a perioperative process (Figure 5). This process is composed by three main sub-processes from patient admission to discharge – preoperative, intraoperative and postoperative.

Figure 5: Perioperative process.

The preoperative process begins with the patient consultation where surgery proposal is approved and ends with the patient's transference to the OT. The intraoperative process goes from the transference of the patient to the OT until the transference to the Post-Anesthetic Care Unit (PACU). The postoperative process starts with the transference to the PACU up until the patient is discharged from the hospital [5].

Each sub-process includes medical and non-medical activities. Considering the workflow of the overall process, it is possible to identify 2 distinct periods in the perioperative process: the non-operative time - time between surgical procedures – which includes the complete preoperative and postoperative processes and some activities of the intraoperative processes (e.g. cleaning the OR); and the operative time – time in which the surgery is performed – which is the majority of the intraoperative process [10].

The perioperative process and its workflow is influenced by several factors, like the set of available resources, which includes personnel – from auxiliaries to surgeons – and physical resources - the specialized equipment, ORs and post-surgical units (e.g. PACU). Other factors may also influence the performance of the system, like the different specialties operating, turnover times, as well as, the patient priority and requirements that must be considered [5]. All these factors may conduct to inefficiencies, uncertainty and variability into the perioperative process and respective workflow. The availability of resources downstream and upstream the perioperative process is necessary to reduce blockings across the process [11].

To reduce inefficiencies, several strategies for operating room scheduling can be explored – for example, open schedule and block schedule. Block schedule is the most used in planning the operating rooms in the SNS including the hospital under study. There is a "block schedule", named Master Surgical

Schedule (MSS), which assigns a specific time slot and operating room to each specialty. In some cases, there are operating rooms dedicated only to urgent surgeries or a certain specialty due to the requirement of specific equipment. Otherwise, in the open schedule, the surgeon has the autonomy of scheduling the cases for any workday.

The scheduling process needs to consider 2 types of surgeries: elective – surgeries that may be scheduled in advance, due to the stable state of the patient that does not require an emergent procedure; urgent – surgeries that must be performed without delay, due to the patient's risk of permanent disability or death.

On other hand, it is also possible to reduce the inefficiencies on the operational process. To achieve this, it is required to have a complete knowledge of each activity performed during the patient's pathway which may be performed by using process mapping (e.g. Figure 6). With process mapping, there is an unclouded vision patient's pathway and consequently the identification of the resources needed in each step is simplified. To facilitate the mapping of the activities, standardized notation is used, and all resources and communication flow identified.

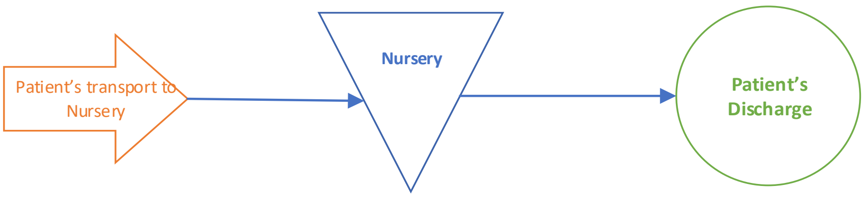

Figure 6: Example of a part of a postoperative process.

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2.2. Case Study

This section provides a context about the problem under study by presenting the organization. Firstly, the CHLN is briefly described to provide a context of the public organization. Then, the case study - HSM's COT - is presented by describing the functioning and operations.

2.2.1. CHLN Description

The CHLN is a public hospital center and is a major reference to the National Health Service. Since 2007, CHLN is composed by two main hospital facilities: Hospital Santa Maria and Hospital Pulido Valente.

CHLN is a tertiary care center and serves the Lisbon and Tejo's Valley regions (Figure 7), providing direct healthcare services to 373 thousand inhabitants and patients from all country, the foreign people in national territory and foreign zones (e.g. evacuations in Timor Leste). Also, CHLN is a direct reference to Primary Care Centers - Alvalade, Benfica, Lumiar, Coração de Jesus and Sete Rios [12].

This organization has a large dimension, and therefore a high complexity associated with the provided services. This is supported by the number of medical staff operating in the facilities (Table 1) and by the organization's production indicators (Table 2) [12].

Figure 7: Area of activity of Centro Hospitalar Lisboa-Norte.

Table 1: Total number of permanent professionals of CHLN [12] [13] *.*

	2016	**2017**
Total number of professionals	6 234	6 290
Doctors	1 398	1 442
Nurses	1 863	1 904
Operational Assistants	1 490	1 408

In both 2016 and 2017, the majority of the permanent professionals of CHLN are directly related with the care provided to patients, namely doctors, nurses and operational assistants [13] [12]. In 2017, 5 503 from the 6 290 permanent professionals are from HSM whereby 1 331 are doctors, 1 621 are nurses and 1 252 are operational assistants [12].

Table 2: Number of patients in each category of CHLN's production plan [12]*.*

	2016	**2017**
External consultation	703 136	714 158
Internment	40 124	40 115
Programmed Surgery	21 103	21 046
Urgent Surgery	4 684	4 935
Day Hospital	13 615	14 731
Urgency	228 205	241 434

The main mission of CHLN is to provide a service of excellence, according to people's needs by respecting the human dignity and following an ethical conduct. Hence, a good and trustful organizational structure, as well as flexible and faster case response are necessary [14],[12].

Although the focus of this work is on the programmed surgeries performed in HSM's COT, it is important to consider the number of programmed surgeries performed by CHLN and compare them with all fifteen institutions of the Lisbon and Tejo's Valley regions (Figure 8). With it, it is possible to verify that CHLN is responsible for, on average, 17% of the performed elective surgeries from January to November 2017, of its activity area [9]. These programmed surgeries consider the ambulatory surgeries and the conventional elective surgeries.

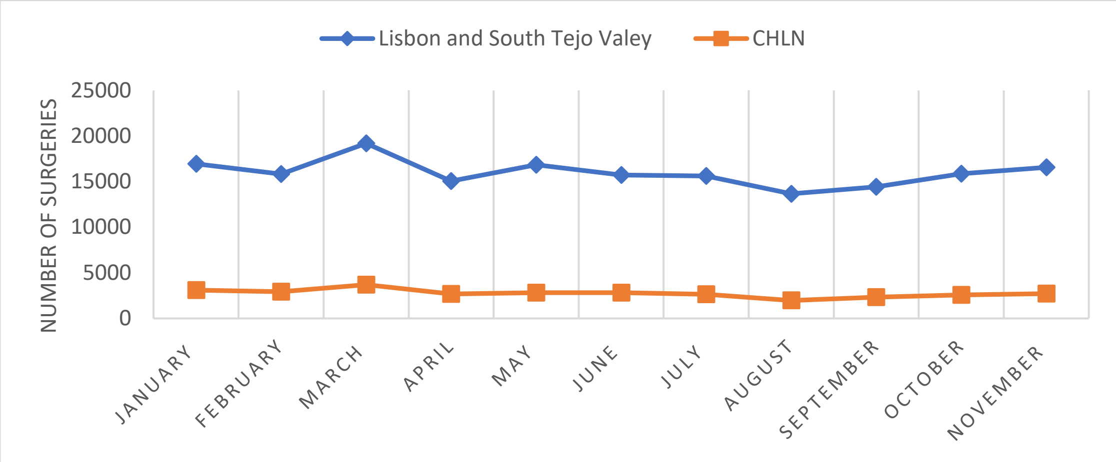

Figure 8: Number of elective surgeries performed from January to November of 2017 [9].

Table 3: Number of elective surgeries performed in CHLN [12].

	2015	***2016***	***2017***
Total number of surgeries	10 946	10 226	8 985
Vascular	640	570	567
Orthopedics	1 473	1 368	1 230
Urology	1 072	1 065	1 115

The number of elective surgeries performed in CHLN is decreasing, as may be seen in Table 3. The decreasing of surgeries is visible in the total number of surgeries performed, vascular surgery and orthopedics. Urology shows an increase of the number of performed surgeries. Despite this decrease of performed elective surgeries, the total number of urgent surgeries has increased (Table 4)

Table 4: Number of urgent surgeries performed in CHLN [12].

	2015	***2016***	***2017***
Total number of surgeries	4 447	4 684	4 935
Vascular	409	304	392
Orthopedics	318	403	360
Urology	332	385	410

Regarding the surgical waiting list, there are aspects that need to be considered as the number of patients in the waiting list, the average waiting time and percentage of patients who are treated on time (Table 5).

Table 5: CHLN's Patient waiting list details [12].

	2015	2016	2017
Total number of patients	7 185	7 471	9 323
Average waiting time (days)	148,93	140,66	158,55
% of patients treated on time	90,82	93,27	90,91

It is visible the increasing of 24.6% in the number of patients in CHLN's surgical waiting list from 2016 to 2017. This increasing reflects on the increased average waiting time (of 12.7%) and percentage of patients treated on time (-2.5%). This increasing of average waiting time reflects the increasing of patients in the surgical waiting list and also of the inefficiencies present in the perioperative process, both in the process and planning.

Therewith, the dissertation's focus is on elective surgeries performed by HSM's COT which will be presented in detail in the next section.

2.2.2. Central Operating Theatre

COT's case study is presented in this section. First, patients are characterized, and the waiting list of the different specialties are presented. Then, its facilities are presented, just as the background of the operational activities – processes and resources. The information described in this section was provided by the COT's Director.

2.2.2.1. COT's waiting list

Four specialties perform surgeries in COT, namely orthopedics, urology, vascular and general surgery. All specialties have several types of patients, who are evaluated to access the pathology's urge for surgery and classified by using a priority system – from high priority to normal (non-oncological disease). This classification defines MGRT [15] to each priority level that may be compared with the actual waiting time on the 30th of November of 2017 (Table 6) [16]. The times presented in Table 6 are average durations.

It is possible to verify that every specialty is complying the stablished MGRT. This accomplishment is not only achieved by COT's teams but also by other institutions. The use of other institutions to perform patients' surgeries arises when SNS cannot fulfill the surgery in established MGRT by providing the patient a voucher. This vouchers are from two types: "surgical voucher" in which the patient may perform the surgery in other public, private or social hospital; or a "transference voucher" in which the patient may perform the surgery in another public hospital [17] [18].

Table 6: Surgical Waiting Time according to patient's classification (days) [16].

Patient Classification	*MGRT*	*General Surgery*	*Vascular Surgery*	*Orthopedics Surgery*	*Urology Surgery*
High Priority – Oncological and non-oncological disease	15	4	6	8	-
Priority – Oncological Disease	45	16	-	5	23
Priority – Non-oncological Disease	60	26	12	28	13
Normal – Oncological Disease	60	22	-	-	55
Normal – Non-oncological disease	270	81	177	155	90

Despite the time, it is also important to present the medium number of patients on surgery's waiting list, in Table 7 [16]. In resemblance to the data in Table 6, the data of Table 7 considers the 30th of November of 2017.

Table 7: Number of patients waiting for surgery [16].

Patient Classification	*General Surgery*	*Vascular Surgery*	*Orthopedics Surgery*	*Urology Surgery*
High Priority – Oncological and non-oncological disease	0	3	2	1
Priority – Oncological Disease	11	-	-	4
Priority – Non-oncological Disease	3	13	3	3
Normal – Oncological Disease	37	-	-	81
Normal – Non-oncological disease	851	940	1037	493

According to Table 7, most of the patients waiting for a surgery in COT is classified in the lowest priority level (Normal).

Although the data in Table 6 and Table 7 refers to average waiting times and it does not suggest a problem in fulfilling the surgeries on the legislated time, it does not imply that the system is efficient regarding the resources utilization and waiting list control. In fact, the report of *Avaliação da Situação Nacional dos Blocos Operatórios* [7] highlights a large and time-consuming patient waiting list for surgery, although this report does not cover the recent years. The available data from CHLN, regarding 2017, says that 87.3% of patients on the surgical waiting list are treated on the MGRT or before achieving it [19], which is over the median time for the hospitals in the Lisbon and Tejo's Valley regions (83.8%).

Despite the number of patients waiting for surgery (Table 7) and the average waiting times (Table 6), it is also possible to consider another moment in the perioperative process – surgical consultation. Considering only the patient's referred by primary care units, it is presented the average waiting times for the surgical consultation for general surgery as well as the number of patients in the waiting list (Table 8 and Table 9, respectively). In contrast to the surgery waiting list and waiting times, patient's classification is composed by only 3 levels - from high priority to normal – and in addition, there is considered patients waiting time for classification by the triage's doctor [16].

Table 8: Waiting time (days) for consultation for patients who come from primary care units [16].

Patient Classification	*MGRT*	*General Surgery*	*General Surgery (Obesity)*
High Priority	30	-	-
Priority	60	16	18
Normal	150	100	68

Table 9: Number of patients waiting for consultation who came from primary care units [16].

Patient Classification	*General Surgery*	*General Surgery (Obesity)*
High Priority	-	-
Priority	3	8
Normal	665	188
Waiting for classification	21	2

It is possible to verify a substantial number of patients and average time in waiting list for patients to the surgical consult. These in addition to the current large waiting list for surgery demonstrates the existence of a urge of improvement of COT.

2.2.2.2. Facilities

COT is a surgical unit located in the 5th floor of HSM. There are 5 OTs in the COT and each one consists in 2 operating rooms, an interchange area – to receive and prepare the patient for surgery - a decontamination room, a work room and a material's storage room, as may be seen in Figure 9. In addition to the storage room in the OT, there is a common storage room to all OTs nearby the OT4 which has provisions for all OTs.

Six of the existing 10 ORs are dedicated to elective surgery of the 4 specialties mentioned previously (section 2.2.2.1) and the remaining 4 ORs are distributed equally between the emergency surgeries from all hospital's specialties and gynecology. The gynecology ORs are not considered in this case due to the different location and functioning.

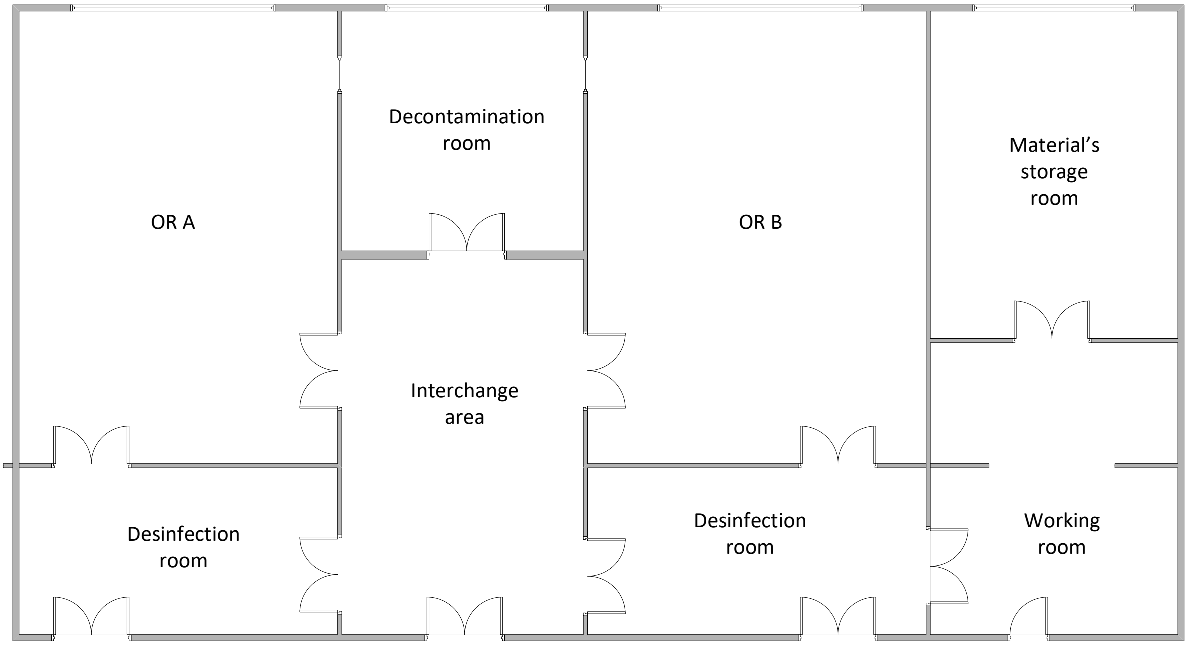

Figure 9: COT's OTs blueprint.

The OTs are symmetric in pairs, namely OT 4 with OT 3 and OT 2 with OT1, with exception of OT5. The specialties are always allocated to the same operating room to reduce as much as possible the transportation of specific equipment (Table 10).

Table 10: Distribution of the ORs by the specialties.

	OR A	OR B
OT 1	Orthopedy	Orthopedy
OT 2	General Surgery	General Surgery
OT 3	Vascular Surgery	Urology
OT 4	Emergency	Emergency
OT5	Gynecology	Gynecology

OT comprises a PACU, functioning 24 hours a day, which receives all patients after surgery, so they can recover from anesthesia. This unit is composed by 12 beds and the patient's length of stay varies between 2 to 3 hours, although they can stay longer when required by the patient's health state.

COT must be supplied by several resources - physical and human - both managerial and medicine specialized.

2.2.2.3. Process

COT's processes are equal to the perioperative processes presented in section 2.1 (Figure 5). The perioperative process is divided into 3 sub-processes (Figure 10) and each activity requires specific human and physical resources.

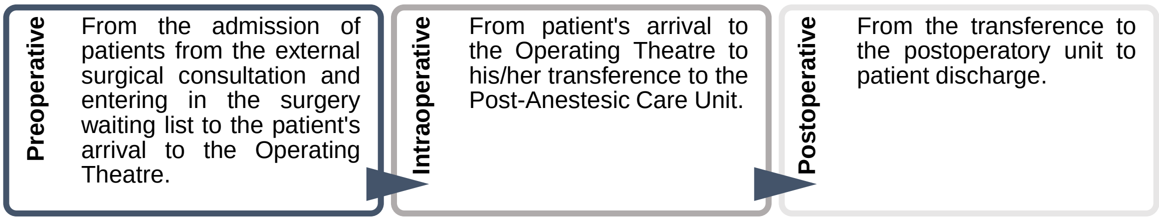

Figure 10: Perioperative process of COT.

The preoperative process starts with external surgical consultation and the entering of the patient to the surgery waiting list. Patients may be referred by other specialty of CHNL, by primary care. After this consultation, the patient is submitted to a range of medical and non-medical procedures which culminate into the patient's transference and arrival to the OT, on the surgery's day or in the previous day. When the patient arrives at the OT, the intraoperative process begins and during all this process the medical team responsible for the surgery follow and monitor the patient. The postoperative process starts with the patient's transference from OT to PACU and it is complete with the patient's discharge from the hospital.

The detailed processes and resources' requirements are studied and mapped more carefully in the next chapters.

2.2.2.4. Surgeries Scheduling

Although this dissertation's focus is on the perioperative process, it is also important to describe the COT's surgeries scheduling due to the need of guaranteeing efficiency and flexibility in the specialties' surgeries coordination and availability of resources.

As mentioned before, scheduling the activities has a significant impact into COT's functioning. Each specialty builds its own surgical schedule in a short-term period (weekly) that must be presented to COT's Director in the previous week. This schedule considers the OT working hours – from Monday to Friday, and each day from 8 a.m. to 8 p.m. -, the required specialties' staff and resources. It may suffer changes during the week according to external factors – e.g. emergent surgical cases from the urgency's unit. The specialty with the largest changes to the planned schedule is orthopedics due to bad surgical case planning, which may occur every day, while the steadier specialties are the general and vascular surgery.

Although the OT working hours are from 8 a.m. to 8 p.m., the specialties do not perform surgeries during all this time with exception of the emergency OT. Therefore, surgeries usually start by 8.30 a.m. and the finish surgical hours depend on the specialty and OR, as seen in Table 11. Considering the emergency OT – OT4 - is the one fulfilling the emergency surgeries from all CHLN, so it works 24 hours during week days and weekends.

Table 11: Specialties' finish surgical hours.

	OR A	Finish Surgical hours	OR B	Finish Surgical hours
OT 1	Orthopedy	3 p.m.	Orthopedy	3 p.m.
OT 2	General Surgery	8 p.m.	General Surgery	3 p.m.
OT 3	Vascular Surgery	3 p.m.	Urology	8 p.m.
OT 4	Emergency	-	Emergency	-

In addition to the OR working hours, the COT also performs afterhours surgeries which are scheduled to overcome the high waiting list – known as SIGIC surgeries – from the incentive system for the recovery of waiting lists for surgery [20]. These surgeries are performed every Saturday and are paid a fee for service, this means that each surgery is considered a project and it is paid individually to the professionals involved in the surgery and to the hospital. According to A. Campos [20], 45% of the fee paid to the hospital is to the surgical team.

Personnel scheduling is performed monthly and suffers several adjustments due to unexpected constraints – e.g. personal affairs, unexpected absences, strikes and the requirement of special skills for a specific surgery. When this schedule is designed, the affinities among the staff members and specific skills are considered due to the better working performance of the team – for example a specific nurse that is more suitable for a type of surgery and respective procedure. Also, it is important to mention that considering COT's case, it is possible to identify that the nurse teams are allocated each shift to the same OT. This means that the nurses who perform surgeries in the emergency OT, only work in this OT regardless the shift hour; the same happens to the other OTs. Considering the shifts, the nurses allocated to OTs responsible for elective surgeries - OT 1, 2 and 3 – have 2 possible shifts from 8 a.m. to 3 p.m. or from 3 p.m. to 8 p.m.. The nurses allocated to the emergency OT – OT 4 – have 3 possible shifts: from 8 a.m. to 3 p.m., from 3 p.m. to 11 p.m. or from 11 p.m. to 8 a.m..

CHLN uses several softwares during the perioperative process to manage patient's pathway and treatments. These softwares are *CPCHS Soluções Clínicas* (by Glintt) – which allows the visualization of the ORs' schedule and record the patient's medical historic and treatment; Perioperative Suite (by

PICIS) – used by the anesthesiologists to register anesthetics' information and procedures - and *Cirurgia Segura*'s Software - used during the intraoperative process to record patient's and OR's information. These softwares are not integrated which requires registering the same information into all softwares (e.g. postoperative treatment). This leads to inefficiencies since the duplication of information produces losses of time and information.

2.2.2.5. Resources

Providing the right care treatment at the right moment is critical to the patient health and to the efficiency of the services. Therefore, resources are a crucial aspect in care treatment and must be available when needed or in a short waiting period. These resources are classified into physical and human.

- **HUMAN RESOURCES**

The human resources are composed by medical and administrative personnel. There are administrative staff to coordinate the back-office activities and the schedules in the COT. Considering the medical staff, a standard surgical team is established for each surgery and respective timeslot provided by MSS. The surgical team is composed by 1 surgeon that leads the procedure (responsible surgeon), 1 or 2 surgeon assistants that support the main surgeon, an anesthesiologist and 3 nurses - instrument, anesthetist and circulating nurse. The team also includes an auxiliary assistant are not present in the OR during surgery, but they help in the patient's preparation and transportation.

The anesthesiologist service has 92 anesthesiologists in which 64 anesthesiologists are already specialist and the remaining 24 are interns. Considering this and knowing that the interns must be followed by a specialist, there are only 64 anesthesiologists available to integrate COT's medical teams. It is important to mention that the anesthesiologists are not only allocated to COT and PACU but have also other activities within the hospital – e.g. pain consultations, burn unit, prevention units and other surgical OTs – and on holidays, medical certificate and parental leaves. Considering the COT's system, there is required at least 18 anesthesiologists' specialists per day to ensure the activities – 16 professionals to ensure the 2 shifts of the 8 OTs and 2 for the PACU.

Considering the specific case of COT, it is possible to identify that each nurse is allocated each shift to the same OT. This means that the nurses who perform surgeries in the emergency OT, only work in this OT regardless the shift hour; the same happens to the other OTs. Also, the nurse allocated to a specific OT may rotate between OR and function – e.g. in one shift the nurse may the circulant and in the next shift, the nurse may be the instrument nurse. Nowadays, there are 32 nurses allocated to the OTs (except the emergency OT) and 31 nurses allocated to the emergency OT. There is a lack of capacity associated with the nurses' force since to the OTs there should be 52 nurses (Equation 1) and there should be 43 nurses to the emergency OT (Equation 2).

$$6\,ORs * 3\frac{nurses}{OR} * 2\,shifts + 6\,OR\ nurse\ coordinators$$
$$= 42\,nurses + 20\%\ due\ to\ holidays * 42 + 2\ chief\ nurses = 52\,nurses$$

Equation 1: Optimum number of nurses to the OTs with exception of the emergency OT.

$$5\,teams * 7\,nurses = 35\,nurses + 20\%\ due\ to\ holidays * 35 + 1\ chief\ nurses = 43\,nurses$$

Equation 2: Optimum number of nurses to the emergency OT.

The operational assistants in the OT are also in shortage, since there are 28 available, when there is 48 required (Equation 3). In 2017, the operational assistants performed on average 30 hours per week on extra time.

$$8\,ORs * 2\,\frac{operational\ assistants}{OR} = 16 * 2\,shifts = 32 + 32 * 20\%\ due\ to\ holidays = 38 + 2 * 5$$
$$= 48\ operational\ assistants$$

Equation 3: Optimum number of Operational Assistants to the OTs.

As mentioned before, PACU functions 24h a day and it is composed by a service team for each shift. The service team is composed by 1 doctor and 5 or 6 nurses. The nurses are fixed to the unit and are reduced during the night period.

- **PHYSICAL RESOURCES**

Regarding physical resources, there are several materials, instruments and equipment used during surgeries. Regarding the materials and instruments, there are 2 types used in surgery: the one considered standard, which is common to all types of surgeries from different specialties (e.g. scalpel); and the one considered special, which depends on the applied medical technique.

Two particular issues must be considered regarding physical resources: storage and acquisition. There are 2 type of acquisition methods in place: Kanban and consignment. The Kanban is for those materials which has large rotativity and use. In this system, the quantities correspond to the minimum required and logistics validate the orders. The consignment material is the one which has high value and specificity – e.g. prosthetics – and which is not available for immediate use, it requires an order to the supplier.

The storage is performed in the Hospital's central warehouse (Floor -1), the COT's warehouse or in the OR materials' storage room. The clinical material is stored in massive quantities in the hospital's central warehouse and is transported to the COT's warehouse each day to fulfill pre-defined levels – so the professionals do not need to move between floors during surgeries. The instruments present in the OR material's storage room are the ones more specific to the surgeries – e.g. vascular cars.

The equipment used for surgery is specific to a specialty or may be used by all specialties – e.g. X-ray. Considering this, it is stored in the respective OT, namely the OR or in the disinfection room; and in the

COTs corridor which is the passage for all entities who work in the facilities. Due to the technological advances and the lack of revision, there is equipment not used regularly or simply not used that is still in the facilities taking passage space or which is not correctly stored.

In chapter 5, the materials and equipment are generically associated to the process task in which it is required.

2.3. Problem Definition

Surgical procedures are the largest source of admissions in hospitals and the major source of expenses in the organizations. The number of admissions associated with the large surgery's waiting lists are related with inefficiencies (e.g. 10% of patients in CHLN waited longer than the MGRT for a surgical procedure) and the need of surgical vouchers to fulfill the MGRT [7].

Considering all the characteristics of COT's (e.g. chances to surgical plan) and the large and long-lasting waiting lists, the problem of COT is defined as an inefficiency problem. The objective of this work is to apply a methodology to understand and map the perioperative process, identify the flaw points of the system which may lead to inefficiencies and propose solutions. Based on the proposed solutions, a solution proposal for a specific identified flaw point is developed so it can be applied in the real system.

With the problem's development, the expected result is an increase of intraoperative process' efficiency due to the accuracy provided by the tool for OR scheduling and material planning, as well as the defined indicators. Consequently, an increase in efficiency of the overall perioperative process of COT.

2.4. Chapter Conclusions

In this chapter, a problem setting of a general operating theatre is conducted and described. This description includes the surgery type and scheduling, the perioperative process and respective sub-processes, as well as the type of required resources.

A description of the CHLN and, more specifically, the COT is performed to understand the organization and respective operations. CHLN considers the organization's complexity due to the large number of professionals and the large number of patients in the different productivity areas. Also, the CHLN's surgical area is explored. Considering the case of COT, its description is performed considering topics like patients' waiting list and waiting times, facilities, surgical scheduling, processes and resources.

With the understanding of COT's operation and considering the existence of large waiting lists and waiting times, an inefficiency problem is identified. Based on this and excluding the surgeries' scheduling, this dissertation is focused on the organization's perioperative operations.

The next chapter presents a literature review, which addresses topics such as healthcare and OTs, process improvement in healthcare, OR measures and stakeholders.

3. Literature Review

The current project is on a real-life perioperative process in a Portuguese Hospital. Considering this, the literature review aims to provide insights from the work of other researchers which will be use as a baseline to problem development and solving.

Considering the existent literature and the problem understudy, it is important to define a clear search approach to apply. This search approach consists in defining the most suitable search engines and keywords to use during the work development. As search engines, there were used Google Scholar, Science Direct, Microsoft Academic and PubMed, and the sources used were scientific articles, webpages and books. The keywords used were: OR efficiency, OR improvement, OT, perioperative process, OR process mapping, blueprinting.

To address the main dissertation's topics, this chapter is divided into several sections with focus on different themes: Process improvement in healthcare referring the process improvements in healthcare and more carefully the inefficiencies identification and improvements in OTs (section 3.1); the OR measures used to gauge performance, quality and efficiency (section 3.2); the importance of incorporating the key stakeholders in the work development (section 3.3); and chapter conclusions (section 3.4).

3.1. Process Improvement in Healthcare

This section has as basis the problem identification performed in chapter 2 – efficiency problem. Therefore, this section is divided in 2 main topics: inefficiency causes and solutions, and process mapping. Foremost, the definition of efficiency is presented and consequently sources of inefficiency are addresses. The process and the integrated activities identification is an important topic to study, but the methodologies and techniques used to improve the problems are also a source of value in these problems. Therefore, a section with these approaches is also considered.

3.1.1. Inefficiency causes and solutions in Healthcare

Efficiency may be generically defined as the ratio of the useful work performed by a resource or process. In a system, the lack of efficiency is considered an inefficiency - the failure to make the best use of time and resources in an activity or process – and this is a topic to be developed in this section.

The identification of the inefficiencies is not only related with operational processes – as the perioperative process – but may also be related with scheduling – as OR Scheduling [21]. Therefore, and considering the actuation area of this dissertation it is important to establish process as a group of activities completed to achieve a particular outcome [22]. Considering the COT's case study, it is important to start by identifying the process under study, the perioperative process (section 2.1). Before improving the process, it is crucial to identify the different and possible inefficiencies or flaw points that may lead to an urge of improvement.

There is a reduced number of works which identify inefficiencies in the perioperative process as main objective. Therefore, to this section's development, there are used other healthcare specialties/departments' works to provide a solid base. Although not all works are directly linked with the OR, the named inefficiencies are also adequate to OR cases.

As a major inefficiency, there is the delays. Delays are present in all healthcare system and more specific in perioperative processes – as the main cause of not fulfilling the surgical plan for the day. Causes of delays have linkage to patients or the hospital's organization – mainly resources.

Late arrival of patient is an important and unpredictable issue when talking about delays. When in the preoperative process, the patient may cancel or not attend consultations [23] – in preoperative - or be delayed for admission on surgery's day [24] [25] and this may be related to facilities' lack of signalization, which leads to patient's families get lost and retard the arrival [26] – in intraoperative. Considering the OR case and more specific the intraoperative process, the delays in procedures [25] [27] are a major cause for not fulfilling the planned schedule or delaying this schedule. In addition to these, the linkage between stages of perioperative process is clear when the lack or time-consuming exams or labs results [24] [28] [29] – in preoperative - ignite surgical delays as for the 1st case starts and other cases during the day – in intraoperative. A surgery cannot be performed without the patient being clearly informed or even being transferred to OR, so missing or redundant documentation for transferences [26] [28] [30] [27] or consents [25] [30] are a source of case's delays or cancellations.

Considering an OT performing not only elective but also emergency cases, the unpredictability of the emergency cases' demand may also lead to delays in schedule due to postponement of elective cases [24]. Adding to these causes, the prolonged length of stay of patients caused by discharge's delays – in postoperative - is also a source of delay on account of resources' occupation required for other admissions, this may be due to clinical reasons or non-clinical reasons [31].

Considering know the organization's causes – the hospital -, it is possible to define resources as the major contributor to the increasing of lags in healthcare. These resources are physical and human, and both have a relation with inefficiencies in healthcare processes.

Regarding physical resources, the major concerns are beds, equipment and instruments which are crucial to medical procedures and patient's accommodation. Misallocation or lack of beds [24] [31] [32] or organizational problems [33] may cause longer surgical times than expected [24]. Also related with longer surgical times, there are equipment malfunction [25] [34], lack of advanced technological equipment [33] or inadequate equipment in procedure [35] [34] or in the facility by lack of usability evaluation [34] lead to unnecessary time wastes. In addition to equipment, the instruments are also linked inefficiency in the process by lack of checklists to prepare the material so it is prepared based on the knowledge of the circulating nurse [36] which leads to inadequate surgical sets [35] [37]. Moreover, the lack of preparation and standard supplies has also to be accounted as a cause of inefficiency [26].

In addition to the mentioned problems, there are also the problems related with the OR facility. The OR layout may influence the space use by wrong positioning of equipment and furniture [34] [38] which leads to problems in the workspace such as the lack of proximity between work zones [38], movement congestions [39], and the spilling or dropping of items [34]. Also, the disorganized storage of equipment and instruments [38] and inadequate material storage [39] are sources of inefficiency due to time wastes and frequent OR door openings.

The existence of human resources in the healthcare system is critical for its functioning and more even more crucial in perioperative process. The unexpected absence of personnel [24] or lags related directly with nurses and doctors [28] compromises the functioning of the units and in some cases steer to their temporary closure [40] [41]. Medical professionals are not always allocated to OR due to other medical occupations like Doctors consultations and rounds in addition to surgeries. In fact, some authors identified the tardiness in arriving to OR related with the doctor's morning rounds [30], time to evaluate the patients and request exams [29] and waiting for specialist consults [26] [42]. Adding to doctor's delays, there are also delays related with nurses' activities, as the impossibility of accepting patients or collecting them in the specialty unit due to overlapping activities [31] [42] [32] and patient arrive at the nurses' meal breaks [31].

Communication is also considered a source of inefficiency to the perioperative process as a critical matter to patient's treatment. The communication relies on the existent communication system, the capacity of professionals to communicate with each other and to the patient so there is a conscient treatment. There are different ways of communication, in face-to-face communication, the lack of communication between the medical team reflects on the knowledge of patient's care plans in the treatment process [26] [43] [27] [34]. Considering the electronic communication, the failure on the electronic communication system [44] or the lack of a centralized information system [33] also reflects on patient's treatment.

In view of the presented inefficiencies' causes, they can be organized in categories – Arrival of patient; exams and lab results; documentation and consent; emergency cases; beds; equipment; instruments; staff; overlapping activities; consults; communication; OR layout. According to this, Table 28 summarizes the inefficiency causes by categories addressed by the different authors.

The identification of inefficiencies' causes is important due to their importance to overcome and improve the system. Solutions can be developed to reduce or eliminate these inabilities. Not all works presented has as aim the identification or development of solutions. In some cases, the works' objective is only the identification. Despite this, the developed and identified solutions presented by the different authors to are featured in Table 12.

In Table 12, it is verified that standardization is a used solution. Standardization is not only used in instruments and materials [36] [35] [24] but also, by the use of checklists in activities to be performed by the professionals [30] [43], which allows gains in time by a decrease of wasted time and consequently delays in the perioperative process.

After identifying the causes of inefficiency and developed solutions, it is important to understand the path to achieve these solutions, namely the methodologies used. Therefore, the next topic focus on the different methodologies and techniques used to problem solving.

Table 12: Solutions developed by different authors.

Author	Developed solutions
Kuhl [24]	Determine the number of beds to fulfill the demand;
Aaronson et al. [26]	Group supplies for all procedures; Discuss consult's scheduling; Mechanism for facilities' identification; Nurses participate in doctor's rounds;
Balssarre et al. [33]	Reduce length of stay by reducing pre-hospitalization times; Redistribution of beds within departments with fewer performance;
Warner et al. [30]	Standard checklist for resident's morning rounds;
DeGirolamo et al. [29]	Create effective data-driven solutions and the capacity to evaluate impact of incremental changes in workflow processes;
Marsh et al. [42]	Reduce operative time by implementing the proper transportation's documentation and patient's consent; Avoid perioperative changes to the plan;
Franklin et al. [28]	System to identify the surgery readiness – wall flags;
Criddle et al. [32]	Reduce recovery time;
Dyas et al. [37]	Removal of non-used instruments; Formation of new trays (kits);
Copenhaver et al. [36]	Rearrange kits; Place case carts for specific OR cases;
Avansino et al. [35]	Standardize carts and surgical equipment;
Bowen et al. [44]	Improve/optimize paging system by reducing its failures;
Pugel et al. [43]	Introduce checklists;

3.1.2. Methodologies and Techniques in Healthcare

Inefficiencies are caused by different reasons as seen in section 3.1.1. Considering the inefficiencies identified, it is important to understand the possibilities of improving the processes and achieve solutions, also identified in the previous section. In this section and considering the healthcare system and perioperative process, the methodologies and techniques employed by the different works are explored.

Through the previous section (3.1.1) analysis, the techniques and methodologies applied are identified as Lean Methodologies, Graphical Methods – mainly process map - and Simulation. Although it does not include other methods, it is possible to use others to overcome inefficiencies as it is performed by Fong et al. [45]. In these authors' case, a literature review is performed and consequently a set of techniques with focus on improving the efficiency in the intraoperative process are identified. Although these techniques and methodologies are only related with intraoperative process, they may be a base to apply into all perioperative process. The identified methods are: process redesign, parallel processing (e.g. anesthesia induction in specialized room), standardization, lean methodologies, reduction tools – reduction of the material that is not used regularly [45].

Considering this dissertation's focus and to provide a base to the methodology, the focus will be on LEAN methodologies and Graphical Methods since it is the main used in the articles of section 3.1.1..

- **SIMULATION**

Nowadays, efficiency is achieved by redesign of the current processes in the system. In the case of healthcare, it is a complex system and simulation's technique is used for analysis and design of these systems. With the uncertainty of the system as well as the need to test and evaluate the solutions, this technique is considered a mean to achieve the results of implementation without using the real-life system but by duplicating it in simulation programs [46].

Considering the OR cases, simulation is one of the techniques used to address different types of problems. As may be seen by the works addressed in the previous sections, simulation is not the one of most use in the inefficiency problems in the perioperative process [24] [32] . Kuhl [24] used a discrete event simulation model to calculate the adequate number of beds for suitable reconstruction of the Day of Surgery Admission Unit. Although the addressed unit is different – PACU - Criddle *et al.* [32] also used a discrete event simulation with the objective of testing scenarios to improve patient's flow in the unit.

Although it is not used in large scale in efficiency improvement of operations, simulation is of most use in planning problems to size resources.

- **GRAPHICAL METHODS**

Before presenting the graphical methods, it is important to contextualize their use as an analysis tool of the production processes. A production process is defined by Romanowski *et al.* [47] as the set of deliberately undertaken activities that make the desired changes in the subject matter of the work affected by them gradually change.

Production processes can be characterized as strategic processes - related with the management - and operational processes – related with day-to-day operations –, as the case of the perioperative process [47]. With the production processes defined, it may proceed to the graphical methods used to analyze the production processes. A graphical method is uses schemes and visual graphics which allow the illustration, analysis and improvement of the existing processes. Considering the featured works in the previous section, the graphical methods most addressed are process mapping (PM) and value stream map (VSM), but also Ishikawa Diagram and Spaghetti Diagram are addressed in some articles.

PROCESS MAPPING

Process mapping is a graphical method used to map the beginning to end of the process and it exemplify the process' functioning. To perform a quality PM, a good understanding of the process is crucial.

Therefore, the organization's activities have to be well known and its objectives have to be clearly defined [47]. This is achieved by the engagement of the stakeholders – addressed in section 3.3 – since they are the people with major knowledge of processes. The advantages of this method are stated on Table 13, these advantages are according to Antonacci *et al.* [48].

Table 13: Advantages of process mapping according to Antonacci et. al [48].

PROCESS MAPPING ADVANTAGES
Break down the complexity and gather a shared understanding of the reality;
Identify gaps and improvement opportunities adopting a system perspective;
Engage stakeholders in the project;
Identify and align project's objectives and fit intervention to context;
Identify responsibilities and monitor project progress;
Learning;
Ease of use and simplicity of the method and of the physical outcome: the process map.

In healthcare, the PM is upon the patient's journey and has as objective to help the staff to understand this pathway. Since the use of PM is for improvement projects, it can also be seen as a communication tool to support the engagement of stakeholders and consequently develop this projects with them [49] [48] [50] [22] [51]. As examples of PM applied in Healthcare, there is the works of Bouamrane [23], Copenhaver *et al.* [36], Krvavac *et al.* [25] and Aaronson *et al.* [26]. In all cases, the process is mapped and then the inefficiencies and waste are identified.

VALUE STREAM MAPPING

VSM resembles much to PM but it considers the process' flows – information and material flows. Its purpose is the identification and elimination of waste through all process and consequently improvement system's efficiency. Analogous to PM, VSM is a tool of communication which collaboration between all system's intervenients to better acceptance of cultural changes for improvement [47].

This tool is used in Healthcare in 6 Sigma Methodology – explored also in this section. As examples of VSM's application is Criddle *et al.* [32], Franklin *et al.* [28] and Warner *et al.* [30] works. In the first case - Criddle *et al.* [32] –, VSM is upon the surgical services process and the focus is on PACU. On the other hand, Franklin *et al.* [28] use VSM on preoperative process and Warner *et al.* [30] uses it to map the vascular surgery rounding process.

ISHIKAWA DIAGRAM

Ishikawa Diagram aims to establish the relationships between the customer and the supplier and present in graphical vision – "fish bones" - the factors which impact on the process' results. This method should be performed in group and consider the perspectives of different stakeholders by using interviews and brainstorming sessions. With this, problem's causes can be identified upon 5 groups: environment, material, man, management, method and machine [47]. In Healthcare, Ishikawa Diagram has been used to identify factors contributing to inefficiency and delays, as performed by Krvavac *et al.* [25].

SPAGHETTI DIAGRAM

Spaghetti Diagram is a tool used in lean methodologies and it aims to provide a visualization of material and product flow. With this diagram, the path of the materials or products can be tracked, and the circuits identified leading to the development of improvement upon flow [47]. This diagram can be used as a standard tool in simpler systems or can be used in combination with other tools.

In healthcare, spaghetti diagrams are used to study the circuits within the OR – intraoperative process. As an example of its use, there is the study of circulate nurses' circuits within the OR to verify the impact of OR layout in these circuits, as addresses by Bayramzadeh *et al.* [39].

- **LEAN METHODOLOGIES**

Lean methodologies were first developed by Toyota and they are quality improvement methods used firstly in manufacturing industries. Although its use started in manufacturing, lean methodologies application in healthcare has been increasing over the last years as the improvement of efficiency in these systems has been growingly required [52].

Table 14:Waste classification in Lean Healthcare methodologies and examples applied in the OT [53].

Waste Classification	Description	Examples
Defects	Time used to perform something inaccurately and correcting it;	Poor or inefficient verification of processes.
Overproduction	Doing something not required or doing sooner than necessary;	Order a wide range of exams for all patients – e.g. cardiac investigations; when there is no indication of need.
Transportation	Pointless movements through the system as a result of poor layout;	Time spent in transporting patients from one ward to another.
Waiting	Wait for anything is considered waste;	The patient's transference is delayed, and the staff cannot perform their activities.
Inventory	Excess of inventory, movement, storage, etc.;	Excess of supplies in the room which occupies space and become processes less efficient.
Motion	Unnecessary movements between departments to get something required – e.g. move from room to room;	Movements between rooms to get materials or equipments.
Over-processing	Work performed which has no value;	Perform perioperative medical interventions routinely when there is no evidence of benefit for patient's outcome.
Human potential	Not engagement of staff;	

Therefore, Lean is used to improve the process by reducing the waste and betting on value-added activities to propel systems' efficiency. To healthcare, it is important to focus on valuable activities for the patient and reduce the waiting times and errors. With this, waste must be seen in patient's perspective and can be classified in 8 different classes [54] [53] , as seen and described in Table 14.

To overcome the different types of waste (Table 14), 5 steps are applied in lean methodology: (1) understand value – consider the patient's view; (2) observation of the processes operations; (3) visualize the work flow state by VSM and perform a future VSM; (4) completion and approval of the future VSM; (5) implementation. In addition to lean's methodology, different tools in in this methodology can be applied such 5S and Kanban. Kanban is going to be addresses due to its interest in application.

In section 3.1.1, there are problems which apply lean methodologies to identify and overcome inefficiency such as Copenhaver *et al.* [36] who applied it in surgical instrumentation; Krvavac *et al.* [25] on late arrival of patient, lack of documentation or consent, problems with equipment and overlapping activities problems; and Aaronson *et al.* [26] for late arrival of patient, lack of documentation and consent, and communication problem.

KANBAN

Kanban is an important part of the Just in Time production system since it informs the requirements of each workstation through a visual system. Therefore, the system is a pull system and it provides the quantity needed, when needed. As a visual system, Kanban is card-based control system which provides information about the product and its transportation route through the organization. With this, the levels of inventory and its management can be controlled and consequently minimized [55].

To Kanban application, a good knowledge of the product flows and the organization is required. This is achieved by application of VSM to know the processes and respective flows. Then a good prevision of the inventory levels, considering uncertainties, is also required. In this phase, parameters like demand quantities and communication between process steps must be considered. With this, both process improvement and elimination of waste may be achieved [55].

There is a lack of Kanban application in OR. Kanban has been applied in manufacturing industries and in healthcare, the specific case of pharmaceutical supply chains [56] [57], medical consumables [58] and bed management [59]. Despite the lack of existent works with Kanban application, its application in healthcare allows the reduction of waste by reducing the time that the medical staff used to search for supplies [60].

- **6 SIGMA**

6 Sigma was first developed by Motorola and it is a methodology applied for improvement of quality in processes' results. This methodology analyzes and solve operational problems by reorganization of the available resources. Projects in 6 Sigma are based on Plan-Do-Check-Act Cycles and it is composed by 2 methods: Define, Measure, Analyze, Design and Verify (DMADV) and DMAIC which consists on the same first 3 steps of DMADV but the last two steps are Improve and Control [13].

Considering only DMAIC method, it is described in detail. DMAIC is composed by 5 steps: (1) Define the problem with the engagement of the consumers, and consequently alignment of objectives; (2) Measure key aspects such as causes and relations; (3) Analyze by data or process mapping; (4) Improve the process based on step 4 and create a new process state; (5) Control the process state and deviations to the objective [13].

In healthcare, 6 Sigma methodology is integrated with lean manufacturing methodology, resulting in Lean Six Sigma Methodology. Examples of this collaboration are the works developed by Franklin *et al*. [28], Criddle *et al.* [32] and the surgical case of DeGirolamo *et al.* [29].

- **PROCESS REDESIGN**

Process redesign is also used for process improvement with the objective of introducing changes within organizations to improve quality and patient satisfaction [61]. These changes aim to speed the care, identify sources of delay, inefficiencies, unnecessary steps and possible errors in the process that can be corrected by removing or amending the activity. This requires a total rethinking of what is important to the patient and the organization [62] by considering the requirements of the stakeholders (section 3.3) [63]. Therefore, the steps of redesigning the process are: map the process, analyze the problems, think which would be the "ideal" process to the care unit, identify the practical changes to the current process, and test and evaluate the proposed changes [62]. Within process redesign, there is Business Process Redesign (BPR). This methodology is forward described.

BUSINESS PROCESS REDESIGN

BPR may involve the combination of business process, organization structure and information technology (IT) change [64]. To perform a contextualization about this methodology, a general tool and its steps are presented [65] [66] [67]. According to the tool, 6 main steps are defined and composed by different sub-steps: understanding, initiating, programming, transforming, implementing and evaluating.

This methodology can also be considered for organizational change, Teng *et al.* [68] and consider the following elements for organizational change in this methodology: (1) organizational inputs to BPR, initiating process changing – from defining the changing strategy to the engagement of stakeholders into change (section 3.3); (2) selecting changer enablers – that involves the organizational, management, human and technological enablers to change; (3) managing changing implementation – analyzing and managing implementation; and (4) directions of organizational change – structural, management and people [68].

3.2. OR Measures

With inefficiency identification (section 3.1.1) and the assessment of the possible techniques to use in order to overcome them (section 3.1.2), the identification of measures is required. These measures are used to access the process' state and after improvement to evaluate the solution. Therefore, this section starts by identifying the indicators' objectives and the indicators used in the works mentioned in the previous sections.

Performance in healthcare can be measured in different contexts by various indicators and depending on the perspective from which they are evaluated [69]. The frequently monitoring and benchmarking help to continuous improvement of the system under study so it is important to identify the most crucial indicators for performance, utilization and efficiency. Therefore, the selection of the most suitable indicators represents a challenge to the project developer and must be collected by the OR information systems or by directly from the field [70].

These measures are classified into 6 classes – quality, complexity, occupation, cancellations, time and satisfaction - as described in Table 15 [7].

Table 15: Definition of the different measures' classes [7].

Class	Definition
Quality	Indicators that measure the success of the process (e.g. number of performed surgeries considering the total number of surgeries in the waiting list).
Complexity	Indicators that mention the number of distinct types of resources needed to perform a specific task.
Occupation	Measures that consider the utilization of the available resources of the perioperative process.
Cancellations	Indicators that measure the number of cancellations due to different motives (e.g. lack of personnel to perform the surgery).
Time	Indicator that measure times of certain activities or related to the activities.
Satisfaction	Measures regarding patient's satisfaction and requirements due to be one of the most important stakeholders.

There is a lack of standardized indicators in healthcare, more specific in OR when considering the improvement of processes. Despite this, the present section is based on the papers related with the previous sections (section 3.1.1 and 3.1.2) of the literature review. This allows to identify indicators, although they are not directly designated as such, and consequently make a connection between the previous works and the possible indicators that may be adequate to the present inefficiency problem. The identified indicators are presented in Table 29 (appendix).

As mentioned, there is a lack of standardized indicators. Therefore, the identification of common indicators which allow a direct base to this dissertation's problem is not possible.

Considering the lack of indicators in the pretended area, it is possible to identify indicators specific to OR in the planning problems. Once more, these indicators are not standardized but they can also be used to provide a base to define indicators to the COT's process. These indicators are summarized in Table 16. It is possible to identify the common indicators: idle time, overtime and OR occupancy level.

Table 16: Indicators addressed by different authors in planning problems.

Author	Problem type	Indicators
Abedini *et al.* [71]	Surgery scheduling	• Number of OR setups; • Idle time; • Overtime; • OR occupancy level;
Denton *et al.* [72]	Surgery scheduling	• Patient waiting time for surgery; • Patient waiting time for admission; • OR Overtime;
Fei *et al.* [73]	Surgery scheduling	• OR occupancy level; • OR utilization; • Percentage of scheduled patients; • Overtime; • Idle time.

In addition to the previous indicators, the report of *Avaliação da Situação Nacional dos Blocos Operatórios* [7] (evaluation of the current state of the operating rooms in Portugal), address several indicators as seen in Table 17.

Table 17: Indicators used in Avaliação da Situação Nacional dos Blocos Operatórios [7].

Class	Performance Indicator
Quality	• % of adequate records of strategy "safety surgery" implementation (*); • % of cancellations due to artificial variability in the OR; • Rate of non-conformities; • Rate of complete instituted protocols;
Complexity	• Medium investment in special equipment for OR;
Occupation	• Utilization of OR after closing time; • OR overtime;
Accessibility	• % of OR cancellations due to OR motives;
Cancellations	• % of cancelled surgeries; • % of cancellation of surgeries due to artificial variability in the OR;
Control	• No. of protocols and norms regularly audited;
Satisfaction	• Patient's satisfaction index; • OR users' satisfaction index; • OR professionals' satisfaction index;

(*) World security practices that pretends to reduce surgery complications and infections that may result in patient's death [74].

Considering the material present in this section, it is accessed that the indicators depend on the study performed and are not standardized to the processes. Therefore, until a standardized set of indicators is defined, the indicators choice should involve the stakeholders since they have the major knowledge of the processes and consequently are most suitable to discuss and define the intended indicators.

3.3. Engagement of Stakeholders

A stakeholder is any individual or collective entity in an organization who can affect or is affected, positively or negatively, by the involvement and consequently achievement of the organization's objectives [75] .

Stakeholders are the major source of power and knowledge regarding the operations. Their involvement is important to understand the processes (chapters 2 and 5) and to identify the problems in the system – which can be accessed by the papers discussed in sections 3.1 and 3.2.

Although the stakeholders' engagement is performed over decades in industry and services, only over the last decade, their involvement is increasing on operations research and healthcare. This increasing is on account of the crescent number of developed works over the last decade [76]. The increasing of engagement of stakeholders is reflected in literature by the increasing use of "stakeholder" word in the title, abstract or keyword of articles which reveals the importance of this entities into the development of projects [77], [75], [78] . In fact, Hacker *et al.* [79] mentions the existence of drawbacks in traditional research processes due to the detachment of stakeholders – e.g. disconnection between the patient values and the work's goals – so the engagement of stakeholders has been a concern in work's development [79].

In this context, the importance of stakeholders' engagement, during all or part of the projects – preparation, execution and translation -, is mostly due to the need of linking the researchers and organization's goals with the stakeholders, and consequently create long-term relations. In the different project steps, mentioned above, the existence of a wide variety of stakeholders allow a contribution of different settings, understanding levels and goals. In addition, this knowledge provides valuable insights of the organizations about problem's characteristics, participation into solution's identification and the model's construction, acceptance and results [77] [80] [79].

To engage the stakeholders, several principles must be followed so the relationship can be long-lasting as reciprocity between stakeholders, partnerships, co-learning and the most important transparency, honesty and trust. The relationship must start in the project's beginning, so all entities have an active participation, investment in the improvement project and consequently there is a more fruitful contribution. In addition to the mentioned aspects, in this phase, the research goals are defined and the participation of stakeholders promote the objectives' alignment [79].

With the identification of the importance of stakeholder's engagement, it is important to define which stakeholders to involve. Stakeholder's choice must take into consideration the various groups of hospital stakeholders present in the healthcare system to study – e.g. hospital managers, doctors, nurses, patients – and their power on the organization and the study. To achieve the best objective, and to have the best understanding of the system and its functioning, the front-line stakeholders are more suitable to involve. Based on this, another question arises: what is the most suitable way of involving the stakeholders.

Stakeholders' involvement can be performed by different approaches based on the suitable way to address the problem. Therefore, and based on the works addressed in section 3.1, the accessed ways of involving stakeholders are: interviews, meetings and surveys. The different approaches for stakeholder's engagement is seen in Table 18.

Table 18: Approaches for stakeholders' engagement.

Author	Involvement through interviews	Involvement through surveys	Involvement through meetings
Kuhl [24]			x
Krvavac et al. [25]			x
Aaronson et al. [26]			x
Franklin et al. [28]			x
Warner et al. [30]			x
Baldassarre et al. [33]	x		
Criddle et al. [32]	x		
Copenhaver et al. [36]			x
Avansino et al. [35]	x	x	
Dyas et al. [37]	x		
Pugel et al. [43]	x		
Bowen et al. [44]	x		

Considering the number of works present in section 3.1, it is verified that most of them consider the involvement of stakeholders. This involvement is achieved by interviews and meetings. In the interviews' case, the stakeholders do not have an active role in the project's team but otherwise, in meetings, the stakeholders are an active part of the project's team. The data present in Table 18 corroborates the increasing of stakeholders' involvement referred in the beginning of this section and their importance to projects.

3.4. Chapter Conclusions

Healthcare is a service industry. The globalization and modern technologies have affected the patient requirements. Operating Theatres are a source of revenue to healthcare but also a source of expenses. The improvement of this service, with special attention to the waiting list reduction, without improving the usage of resources is a major concern and thus the perioperative process is a critical concern. Furthermore, an improvement of the current perioperative process is required by evaluation of the current status by mapping the process and identifying the flaw points within the process. Subsequently, the proposal of solutions is performed.

The existence of inefficiencies in the perioperative process is challenge for healthcare providers. These inefficiencies depend on patients, physical and human resources, leading to a prominent level of complexity. In addition to the inefficiency identification, several solutions are undertaken. Different approaches have been developed and used over the years, being the most common the lean methodologies.

In this context, several improvement techniques and methodologies may be identified to process improvement, with focus on all perioperative process – simulation, Lean methodology, process redesign, graphical methods – as process mapping and spaghetti diagrams - and BPR. It is also possible to infer that the process mapping is always combined or a consequence of another technique or methodology that is applied (e.g. simulation or BPR). Lean methodologies and BPR are also methodologies addressed more carefully during this literature review due to their ability of rapidly reshape the process. During these topics, a research gap regarding the operational level of OT management, more specifically the Kanban application in OR is identified. This is due to existence lack of papers in the field.

Considering both topics mentioned in the previous paragraphs, the need for evaluating the current status or the results of the performed work rises. So, it is a necessary to define indicators. The identification of the current indicators utilized helps to provide an insight of the measures to apply during the evaluation of the process. These indicators evaluate the systems and help to identify the flaw points in the process. In resemblance of the lack of application of Kanban, there is a lack of standardized indicators in the OR field.

The involvement of the stakeholders is of most importance to develop the present work. Stakeholders have the specific knowledge about the current operations and environment of the organization that allows to understand the processes and provide a most suitable approach to the problem. This involvement enables to enrich the dissertation by helping to better identify the problems, the perioperative process and develop solutions.

Based on the described problem (chapter 2) and the performed literature review (chapter 3), a methodology is presented in the next chapter. This methodology aims to identify the current perioperative process and flaw points; and aims to help the development of the problem solution. In addition, a base for results evaluation is provided.

4. Methodology

In this chapter, a methodology with the aim to improve COT's efficiency is identified and described in detail. Section 4.1 presents the methodologic tool; section 4.2 introduces the difficulties of the proposed tool; and section 4.3 closes the chapter with some conclusions.

The methodology presented has as base the COT's problem – inefficiency problem – described in chapter 2, and the methodologies featured in the literature review (section 3.1.2) to overcome the work's identified inefficiencies. Based on that, the methodology is developed and described along this chapter.

4.1. Methodology Tool

In chapter 3, different methodologies are addressed to overcome the identified problems. With this, and knowing the objective of this dissertation, a tool based on a single methodology cannot be applied.

The methodology (Figure 11) is composed by 4 steps included in BPR methodology which intends to improve the efficiency and efficacy of processes through a reengineering process – adapted from the tools of Palma-Mendoza *et al.* [66], Bertolini *et. al* [67] and Motwani *et al.* [65] –, and Lean Methodology which aim to integrate tools for continuous improvement in processes – adapted from Liu *et al.* [52]; Kimsey [54]; and Kasivisvanathan *et al.* [53]. The indicated methodologies are not directly applied since they have no direct connection with the COT's system and not all steps can be applied in this case.

The different approaches included in this methodology are introduced and connected to develop a unique tool that is most suitable to the problem. Step 1 – understanding – includes the basic tool based on Motwani *et al*. [65], Palma-Mendoza *et al*. [66] and Bertolini *et al.* [67]. All tools include steps to understand the functioning of the system, define the objectives of the work to develop and engage the stakeholders. These steps are unified to provide the step 1 of this dissertation and consequently allow the problem identification and understanding of COT collaboratively with the stakeholders.

Steps 2 is adapted from Bertolini *et al.* [67], Liu *et al.* [52] and Kimsey [54]. The process map is used by Bertolini *et al.* [67] and Liu *et al.* [52]; and the identification of the flaw points is performed by Bertolini *et al.* [67] and Kimsey [54]. Step 3 is the methodological step with less adaptation from other authors, the use of Spaghetti Diagrams is performed by Liu *et al.* [52] and Kasivisvanathan *et al.* [53] to evaluate OR circuits. Despite this, the tool for both OR scheduling and material planning is not present in the literature. Therefore, this tool provides a new method of planning both OR occupancy and sugeries' scheduling and the material planning.

Step 4 is adapted from the tools presented by Motwani *et al*. [65], Palma-Mendoza *et al*. [66] and Bertolini *et al.* [67], since all 3 authors implement the solutions developed. In addition, Motwani *et al*. [65] and Bertolini *et al.* [67] monitor the solutions and evaluate the progress.

A scheme of the proposed tool is presented in Figure 11, and a brief description of the steps is performed forward.

STEP 1 – Understanding

This phase is initiated by problem identification. The relationship between the dissertation goals and re-engineering is explored to develop a cross-functional cooperation that allows the changes into the current state to be performed. These changes involve a sharp vision of the objectives to achieve into a successful project due to its high complexity and dynamism [66].

The key tasks of this step are the identification of the problem and engagement of the involved entities by recognizing the re-engineering goals as well as understanding the organization's environment. To this end, several meetings and interviews with stakeholders are conducted to understand the entities view of the processes and environment [65] [66]. Considering the involvement of stakeholders, it is important to consider all professionals from COT's Director to the Operational Assistants. In this 1st phase, the involvement is performed considering the COT's Director and the Chief Nurse.

After developing the first step, it is possible to specify the methodology to apply. This methodology is chosen based on the identified problem, the environment's understanding as well as the perception of the most suitable approach to follow.

STEP 2 – Procedure

The focus of step 2 is the identification of the current process. For that, a process map is designed to facilitate the activities and element's identification. In each process activity, the identification of the activity type, description and time is required. The resources – physical and human – are also defined and discussed.

To map the process, the involvement of the stakeholders is required and performed through interviews and meetings. The stakeholders have the knowledge of the processes and the needs of each activity. Visits to the facilities and on-scene processes follow-up is also required [67]. In addition, observations to the process are performed to better understand its functioning and the involvement of the professionals is required (e.g. nurses and anesthesiologists; despite the already involved).

With the perioperative process mapping, the identification of flaw points can be performed. This identification is performed qualitatively, and it is based on the observation of the process, and on the interviews and meetings with the stakeholders. After identifying the flaw points and carefully describe them, the next step is applied.

STEP 3 – Re-engineering

The identification of the flaw points in step 2 allows the proposal of solutions to overcome the identified flaws, which may reflect in inefficiencies to the system. The solutions proposed are based on the literature review (chapter 3) and adapted to achieve the objective – proposes which increase the efficiency of the system by correcting the detected inefficiency.

Based on the solutions proposed, 2 of the solutions is chosen by the dissertation's developer – Intraoperative indicators and tool for OR Scheduling and Materials Planning - to be developed and provide a base for its implementation in COT. By choosing this solution, an evaluation of the OR circuits - to support the flaw identification - is performed using Spaghetti Diagrams.

Spaghetti Diagram is a graphical tool used in lean methodologies which aims to provide a visualization of material and product flow. In this dissertation's case, the Spaghetti Diagrams allow to identify the circuits performed by the circulating nurse, anaesthesia nurse and the anaesthesiologist and verify the validity of the flaw point identified and the requirement of the solution. This was also performed by Bayramzadeh *et al.* [39] to access the circulating nurses' circuits within the OR.

The solution proposed involves the development of a user-friendly tool that allow the OR scheduling and material planning – material common to all type of surgeries – and define the quantities required in the OR for the day according to the performed surgeries. In addition to this solution, a set of indicators are defined so the process and solution implementation can be evaluated – future work.

During this step, the re-engineering, the involvement of the stakeholders is of most importance to identify the flaw points and to discuss the solutions and its development. This is due to the importance to adequate and sustain the proposed and developed solutions.

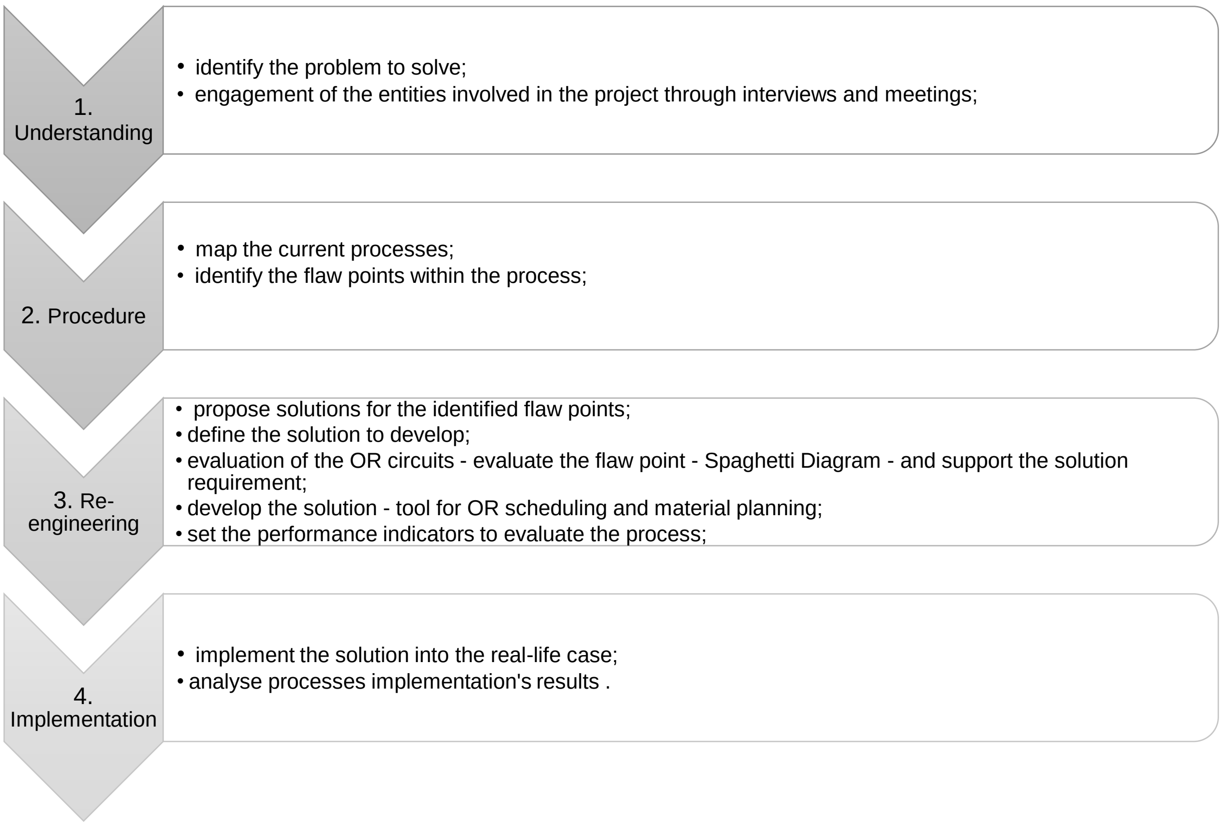

Figure 11: Methodology steps.

STEP 4 – Evaluation and Implementation

This step includes the evaluation and implementation of the re-engineered process in the hospital [66].

With the implementation, a control and analysis of the results is required to verify the efficiency improvement. This control and analysis are performed by application of the indicators defined on step 3.

4.2. Methodology Difficulties

The identification of the difficulties experienced in the methodology application is essential to work development. These difficulties include the following aspects:

- The engagement of stakeholders is not easy. The medical team leaders – namely COT's Director and Chief of Nurses – are interested and cooperative during the dissertation period. Although, some medical professionals are not open to cooperate in a first phase. This difficulty is overcome by explaining the work's objectives and encourage the medical teams to participate;
- The complexity and dimension of the perioperative process lead to difficulties in the identification and clarification of relationships between activities and resources. Therefore, the division of the perioperative process in its 3 subprocesses allows to simplify the activities' identification;
- The system in study is dynamic. Considering the period in which the data, for steps 2 and 3, is collected – April to July and July to September, respectively – some flaw points may not be clear to identify or are not visible. There are construction works in an OT from July 15 to September 24, so the specialties are reallocated through the remaining COT's ORs. Therefore, to achieve valuable results, the data collection must be done when the specialties were operating in the original OR;
- The existence of several surgical teams, which may have dissimilar experience, influence the surgical duration – a less experience surgical team may need higher surgery duration.
- The relationships among stakeholders are complicated to manage. Therefore, conflict management is required to obtain reliable information from the medical teams.

4.3. Chapter Conclusions

In this chapter, the methodology tool to solve the COT's problem is presented. This tool is an adaptation of basic tools available in the literature and is composed by 4 steps that include different methods - BPR and Lean methodology. The difficulties in implementing the methodology are also highlighted.

The application of the methodology result in a re-engineered process that has the potential to allow the improvement of COT process and day-to-day operations.

5. Results Presentation and Discussion

This chapter presents and discusses the results obtained by direct application of methodology and each section of this chapter corresponds to a different methodological step – process map and identification of the flaw points to step 2; and recommend solutions and solutions' development to step 3. With the knowledge of CHLN's administration, the observations within COT are performed for 6 months – April to September - to develop the dissertation.

To have a good understanding of the perioperative process and, consequently, to develop this chapter, the engagement of the stakeholders is crucial, and it starts by involving the COT's Director through interviews. His involvement helped to identify the COT's system as the perioperative process composed by the patient, resources and information flows, as shown in Figure 12.

In Figure 12, it is possible to observe COT's process as the perioperative process. The perioperative process is composed by 3 subprocesses – preoperative, intraoperative and postoperative – which contemplates the information flow, patient flow and the resources flow.

With the understanding of the major components of the system (Figure 12), the first draft of the process map is performed in a macro scale by use of Operations Management notation and Visio software [81].

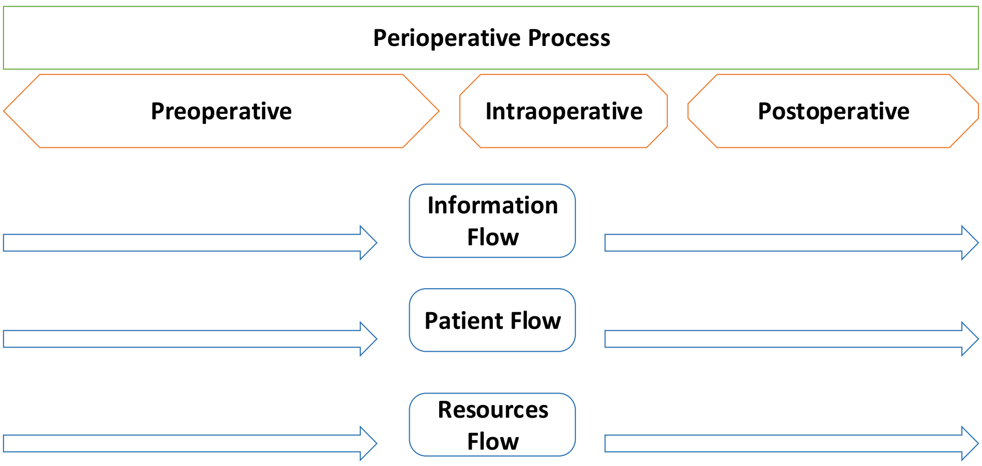

Figure 12: COT's system.

After the first draft, other stakeholders are engaged, namely COT's Chief Nurse, OR nurses and anesthesiologists. In addition, visits to the unit are performed which provide observation moments to help describing more carefully the process stages and consequently the micro scale process is mapped.

With the process map, the description of each process task is undertaken to provide an insight of the process. Then the flaw points are identified which are the base to the proposed solutions.

5.1. Process Mapping

In this section, the perioperative process is mapped, and its activities described according to the current practices in COT. The characterization of each activity is then undertaken (e.g. operation and transport) and the required physical and human resources are stated.

The perioperative process is a complex system which requires a large knowledge of the organization and its practices to be mapped. The process mapping is performed featuring direct observation on sight and meetings with the stakeholders (e.g. COT's Director and Chief Nurse). The process considers the patient path through the system from the external consultation – surgical requirement confirmation – until the patient's discharge from the hospital after surgery. In resemble of what is described in the literature [5], 3 subprocesses within the perioperative process can be identified: preoperative, intraoperative and postoperative process.

5.1.1. Preoperative Process

COT's Preoperative process is identical to the one presented in problem description (section 2.1, Figure 5). It features all activities from the identification of surgery requirement in the external surgical consultation and consequently entering in the surgery waiting list, until patient's arrival to the OT (Appendix, Figure 32 and Figure 33).

This process starts with the external surgery consultation in which the doctor evaluates if the patient's pathology requires surgery or if it can be treated without surgery. The external consultation involves the patient - who may be directed from another CHLN's specialty or from a primary or secondary care center - and the doctor that conducts the consultation (Figure 13).

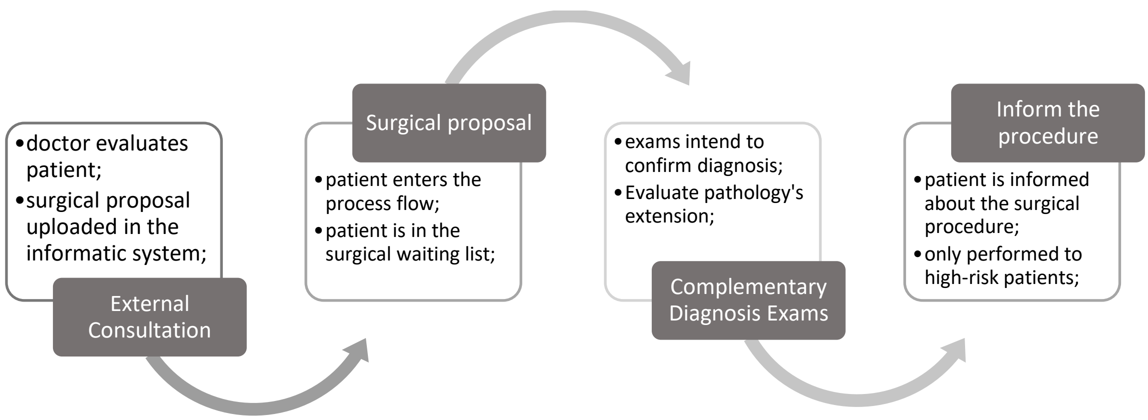

Figure 13: Scheme of the preoperative process from external consultation to patient's information of the procedure.

Once the patient's pathology is evaluated and confirmed by a positive surgical decision, the patient enters the process flow and a surgical proposal (Figure 13) is developed and uploaded in the informatic system (CPCHS Soluções Clínicas). With the doctor's surgical approval, the patient is finally registered in the surgical waiting list. Then, the patient is submitted to Complementary Diagnosis Exams (Figure 13) with the objective of confirming the diagnosis and evaluating pathology's extension. These exams are: blood analysis, electrocardiogram (ECG) and thorax tele radiography (chest x-ray), and they are performed for all the specialties. Although these exams are basic and standard requirements, more specific exams to assess patient's condition may be needed depending on the specialty (e.g. orthopedic surgery may require a computed axial tomography (TAC)). Thereafter, the patient has a waiting period until it is recalled to the hospital to be informed about the surgery to be performed and the required technical procedure (Figure 13). Nowadays, only the high-risk patients are informed about the procedure to be followed due to lack of doctor's availability to perform this step.

Hereafter, the patient is submitted to an Anesthesia Consultation (Figure 14) in which the anesthesiologist evaluates if the patient is suitable for surgery due to the surgical risk and anesthesia classification, namely American Society of Anesthesiologists (ASA) Physical Status Classification System [82]. Nowadays, the hospital is not capable – due to lack anesthesiologists and possible lacks planning - to perform the anesthesia consultation to all patients and thus only the patients with high-risk – complicated surgical pathologies and additionally pathologies that may reflect on surgical complications - or in urgent situation receive this type of consultation before the surgery. The remaining patients are only seen by the anesthesiologist during internment in the day before the surgery. When a patient requires surgery in a brief period and the patient has not been yet in the anesthesia consultation, the surgeon may contact the anesthesiologist to faster the process.

In face of suitability provided by the anesthesiologist's evaluation, the patient waits until the hospital admission. Otherwise, the anesthesiologist requires more complementary exams to perform a deeper evaluation of the patient. These complementary exams focus on the patient's pathology, e.g. stress tests and echocardiogram. With the results and anesthesiologist's clearance, the patient waits for the surgery scheduling and consequently for the internment. Otherwise the patient does not have surgery until (s)he is studied in detail to overcome the identified clinical barriers to surgery.

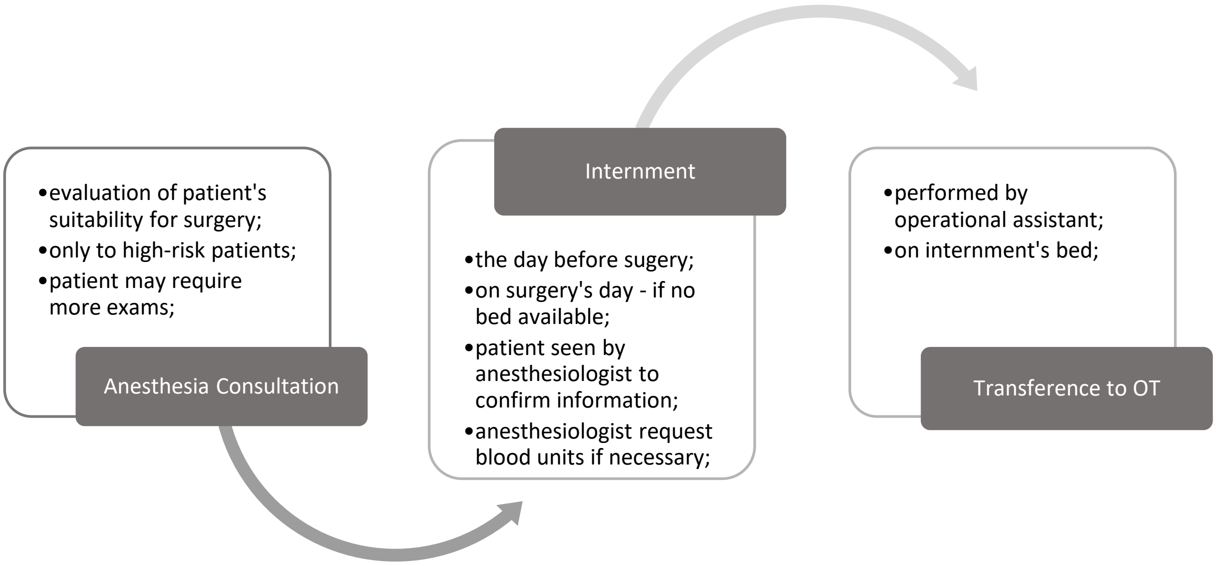

Figure 14:Scheme of the preoperative process from anesthesia consultation to transference to OT.

When there is no capacity to perform the Anesthesia Consultation, the patient after performing the Complementary Diagnosis Exams waits until the surgery is scheduled and consequently the internment, which is performed in different places depending on the patient’s priority – e.g. normal priority patients wait at home. When the surgery is scheduled, the internment occurs (Figure 14), and it is preferentially on the day before the surgery, but it may be on surgery’s day – when there is no bed available. When, on the surgery’s day, there is no beds available, the surgery is postponed, and the patient waits until a bed is available during that day; if no bed becomes available during the day, the surgery is cancelled, and the patient is rescheduled. During the internment and before the surgery, the patient is seen by the anesthesiologist to confirm the patient data, namely the previous surgeries, allergies and clarify the procedure and any doubt that the patient might have related to surgery. The anesthesiologist also evaluates the patient’s exams performed during preoperative process (when there were no previous Anesthesia Consultation) and the need to request blood units to be available during surgery. In case of not having the exams, the patient performs the exams on the surgery day, when possible, or the surgery is cancelled and rescheduled to allow for the patient fulfilling the exams requirement.

On surgery’s day, the patient is transferred from the internment unit in the internment bed by an operational assistant to the entrance interchange area of the OT (Figure 14). When the patient arrives at the interchange area, the preoperative process finishes, and the intraoperative process starts.

With knowledge of the process, it is possible to access that there are several resources which can be considered critical due to its requirement to the activities’ production. The patient is the critical human resource as well as the surgeon who confirms surgical requirement and the anesthesiologist which evaluates the suitability of patient for surgery. Considering the activities, the consultations are the ones requiring a better medical knowledge and importance to the right evaluation of patient’s pathology. In addition, the blood availability is also critical to the process, but its criticality is only visible on the intraoperative process – once it is in this process that it is used.

5.1.2. Intraoperative Process

As seen in section 2.1 (Figure 5), intraoperative process starts with the patient's arrival to the OT, namely the interchange area, and finishes with the transfer to PACU (Appendix, Figure 34 and Figure 35).

The patient arrives at the interchange area of the OT (Figure 15), the anesthesiologist and anesthetic nurse receive the patient and the case is discussed with the nurse who follows the patient. With help of the operational assistant, the patient is prepared to enter the operation room, namely the removal of the internment clothes and transference from the internment bed to the surgical marquis. This movement depends on the patient’s mobility and can be performed by the patient or by the operational assistant present in the room. In parallel with the preparation, the patient is seen by the anesthesiologist to confirm the data collected in the internment. Then, the patient is transported to the OR.

In the OR (Figure 15), the patient is prepared to receive anesthesia. This preparation is composed by switching on the monitors and ventilator and connecting them to the patient. All this process is communicated to the patient, so that (s)he is informed and keep calm. In parallel with patient's preparation, the circulating nurse is bracing the required material to surgery. Then, the anesthesia is induced – according to ASA classification and patient type. After patient is anesthetized, the anesthesiologist and the nurses intubate and position the patient according to the surgical procedure that is going to be performed; at the same time, the surgeons are disinfecting and preparing themselves. All anesthetic information is collected from the moment the patient starts the anesthesia's preparation until the patient wakes up, with use of PICIS software.

When all the conditions are satisfied – patient is positioned, all medical team is in the OR and prepared, and the anesthesiologist approves the surgery's beginning, the surgery starts. The duration depends on the performed procedure, the type of surgery – laparoscopic or conventional – and the surgeon in charge (if it is an intern-doctor in training to be a specialist -, it is expected to take longer). The procedure's type and functioning also influences the materials required. Compresses are registered on the operating software during the surgery – *Cirurgia Segura* – to be controlled and checked after surgery. In addition, CPCHS is used to record surgery's information.

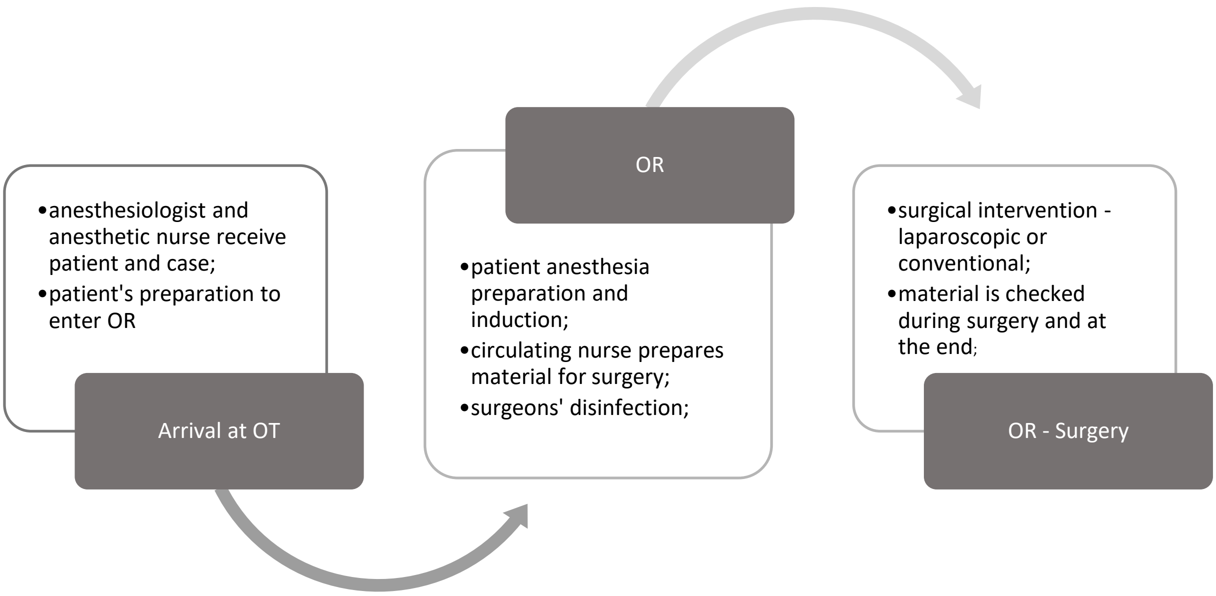

Figure 15: Scheme of intraoperative process from patient arrival to OT until surgery.

After surgery (Figure 16), the surgeons leave the OR and only the nurses and anesthesiologist remains on site. The instruments' nurse cleans the sterile field and the patient. In parallel, the circulating nurse confirms the used material, namely the compresses, and requests a bed and transport for the patient. The anesthesiologist administers the required medication and wakes up the patient. During this, the anesthesiologist and the anesthetic nurse communicate with the patient to verify the patient's response capacity and to relive the patient.

When the patient is responsive, (s)he is transported in the surgical marquis into the interchange area and is prepared to leave the OT - transfer to a post operatory unit's bed with the help of the anesthesiologist, nurses and operating assistant. During this, the OR is cleaned and disinfected by the operational assistant. The waste created during surgery is removed from the OR and accommodated in the correct containers. In the case of the sterilized instruments, they are taken to the decontamination room to be processed and send to sterilization. After this, the material required to the next surgery is prepared according to the surgery type. During this preparation it may be required to get material from other storage room outside the OR – the OT storage room or the floor common storage room.

When the patient is ready for transport (Figure 16), the patient is transported into the post operatory unit that may be the PACU, Intermediary Care Unit (IntCU) or Intensive Care Unit (ICU) depending on the patient's health state. It is important to mention that, when there are no available beds in the postoperative units, the patient waits in the OR at the OT's interchange area until a bed is available. In addition, if the anesthesiologist evaluates the patient and verifies that (s)he has no conditions for transportation, the patient remains in the interchange area (section 2.2.2.2, Figure 9) – OT area to receive and dispatch the patients - until conditions are achieved. These facts constrain the following surgeries and consequently delays may occur.

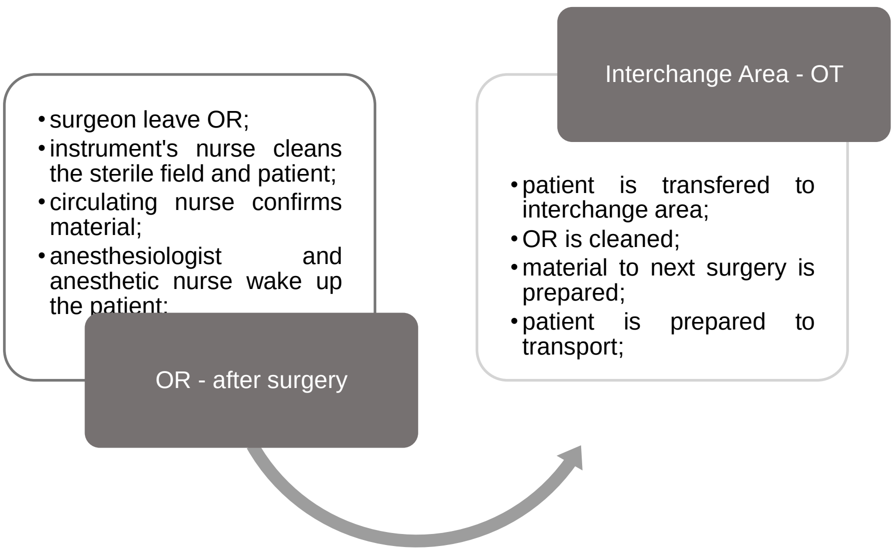

Figure 16: Scheme of intraoperative process from surgery's end to transference from OT.

With the arrival of the patient to the OT, the intraoperative starts and the patient remains in the OT facility during all activities. In this process, the medical team is critical to perform the activities, namely the circulating nurse, the instrument nurse, the anesthesia nurse, the anesthesiologist and the surgeons. Even not involved in surgery, the operational assistant's role is also important during this process due to the interaction and preparation of the patient. As important activities, there are the surgery – since it is a sensible step to patient's treatment and the activity's performance influence the patient's quality of life -, the anesthesia and the preparation of material – since the right preparation of required material influence the surgery outcome, possible delays and accuracy to the surgical plan. Intraoperative process ends with the transportation of patient to the post operatory unit, with which the postoperative process starts.

5.1.3. Postoperative Process

Postoperative process begins with arrival of the patient into the post operatory unit and ends up with the patient discharge, as may be seen in section 2.1 (Figure 5). The process map is available in appendix, Figure 36 and Figure 37.

The patient's path after surgery is dependent on patient's health state, leading to different situations:

- If the patient is critical and requires close monitorization by a health professional, (s)he goes directly to the ICU;
- If the patient is not critical but requires more monitorization, (s)he goes directly to IntCU;
- If the patient's health state is considered non-critical, (s)he goes to the PACU.

It is important to mention that it is considered non-critical health state when the patient is stable and does not require special care or constant monitorization.

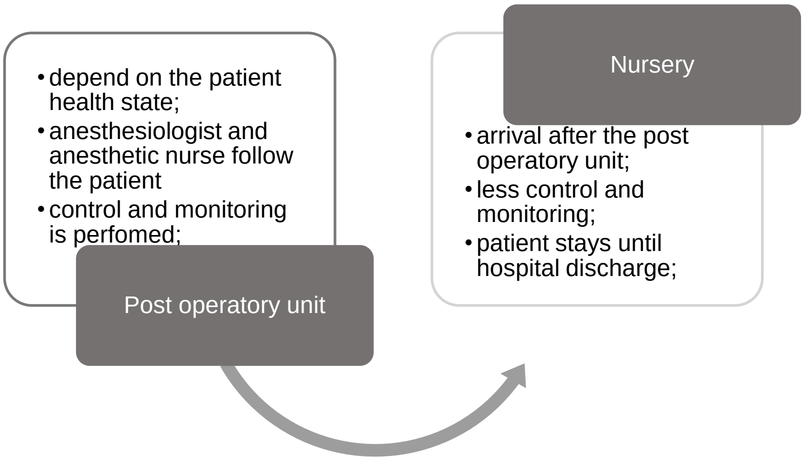

Figure 17: Scheme of postoperative process.

In PACU's case (Figure 17), the patient arrives at the unit and the bed is placed on the available position. The patient is controlled and monitored until the conditions for discharge to nursery are observed. In parallel, the anesthesiologist and the anesthesia nurse with the PACU's doctor and nurses perform a briefing of the case. When the patient has conditions for discharge, (s)he goes to the nursery.

Considering the other units, the procedure is similar, the patient is controlled and monitored until (s)he has conditions to go to another unit (knowing that the patient cannot go to the PACU since this unit is destined for anesthesia recovery so, after being in other unit, this does not apply). Thereafter, the transfer to the next unit is once again dependent on the health state of the patient. If the patient is able, he/she is transferred to the nursery (Figure 17). Otherwise, the patient remains in the unit or is directed to the suitable unit – ICU or IntCU - before going to the nursery. Once the patient enters the nursery and he/she is qualified, the hospital discharge is provided by the surgeon.

The postoperative process of the patient is directly related with his/her health state and it is a critical process for total recovery. The health state of the patient influences the patient path, i.e. the patient can be transported to UCI, IntCU or PACU depending on if monitorization is required.

5.1.4. Resources

The tasks and activities performed in the perioperative process may be characterized as operations, transportations or queues. Each activity involves several or none human and physical resources. Considering this, it is possible to summarize the activities' classification and required resources (see appendix, Table 30).

Table 30 shows that the most required human resources are anesthesiologist, both circulating and anesthesia nurse, and operational assistants. Beds, the OR, surgical marquise, instruments and equipment are the major physical resources required. All these resources are required to perform the considered critical activities – surgery, internment and transportation -, therefore they may be considered critical to system's development since they influence the upstream activities. Moreover, the right planning of these resources is critical to heal overcome the related flaw points – e.g. lack or misallocation of beds.

In addition, the existent softwares are also a requirement during all perioperative process. This softwares, namely PICIS, CPCHS and *Cirurgia Segura*, are used to support the activities and their description is addressed.

- **SOFTWARES**

During perioperative process, different softwares are used: *Cirurgia Segura* (Safe Surgery); PICIS – CareSuite Anesthesia/ PACU Manager/ Critical Care; and *CPCHS Soluções Clínicas* (Figure 18). These softwares do not communicate between themselves thus requiring replication of information and in certain cases results in loss of information.

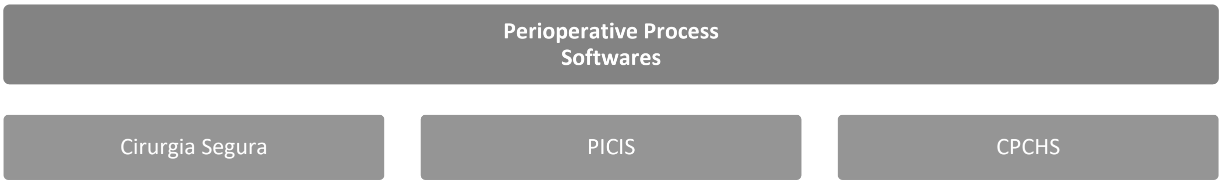

Figure 18: Perioperative Process' Softwares.

Cirurgia Segura (Safety Surgery)

This software is prepared to be used in the 3 subprocesses of the perioperative process. Considering the case under study, the software is only used in the intraoperative process by existing only in the OT and recording specific information of this process stage (Table 19).

Table 19: Cirurgia Segura's information record.

Software	**Main topics**	**Detailed topic**
Cirurgia Segura	Time	○ Time the patient arrived at the OT; ○ Time the patient arrived at interchange area; ○ Time the patient entered the OR; ○ Time of anesthesia induction; ○ Time of surgery's initiation; ○ Time of surgery's end; ○ Time of leave the OR; ○ Time of leave the OT;
	Surgical Team	Surgeons, nurses, anesthesiologists;
	Patient's positioning and required surgical material	e.g. pillow and arm support;
	Surgical field preparation	e.g. alcoholic solutions;
	Electrocoagulation	
	Materials' record	e.g. surgical compresses – small, medium and large;
	Patient's closure	e.g. description, phase;
	Patient's evaluation when leaves the OR	conscience state, motive response; reflexes – response to pain
	Observations	e.g. temperature, blood sugar;

PICIS – CareSuite Anesthesia/ PACU Manager/ Critical Care

This software's objective is to help to manage patient flow while delivering focused care by, for example, automatic collection of important patient information, supporting documentation, clear visualizing fluids and medicines, enhance communication through the patient pathway. This software is used in both intraoperative and postoperative processes.

Considering the intraoperative process, PICIS registers the information in Table 20. PICIS is also used in the postoperative process by the ICU once there is the need to monitor the patient more carefully. In addition, it is possible to access the anesthesia information from former surgeries and to see and request blood analysis and imaging examinations.

Table 20: PICIS's intraoperative information record.

Software	**Main Topics**
PICIS	Times - patient’s entrance in OT, patient’s preparation to surgery, patient’s anesthesia induction, end of surgery, patient awakening, patient leaves the OR;
	Patient’s information records (e.g. ASA);
	Records of the hydric balance;
	Monitor’s data (e.g. cardiac arrest or arrhythmia);
	Used medicines;
	Anesthesia used materials;

CPCHS Soluções Clínicas

This software’s objective is to follow the patient journey during the perioperative process – preoperative, intraoperative and postoperative. As mentioned before, the software registers information of all 3 subprocesses of the perioperative process (Table 21).

Table 21: CPCHS' information record

Software	**Main topics**	**Detailed topic**
CPCHS	OR overview;	Complete vision – general information, surgical interventions, individuals, diagnosis; Abbreviated vision;
	Preoperative	Initial evaluation; pre-surgical validation;
	Intraoperative	○ Positioning; ○ Operative field; ○ Electrocoagulation; ○ Material’ counting; ○ Closure; ○ OR outbound evaluation; ○ Observations
	Postoperative	Closure; working plan; post-surgical validation;
	Internment abstract – summary of the patient’s interment;	Specific data; eliminated products; hydric balance; episode report; nursing notes; nursing history; collected data; wounds; OR summary;
	Transversal historic	Monitoring; administered therapeutics; non- administered therapeutics; nursing notes; life vital parameters; valid interventions; fulfilled interventions;

It is possible to see duplication of information among the 3 softwares in Table 19, Table 20 and Table 21. The duplicates information regards the time - entrance time in OT and the time for anesthesia induction –, the positioning of patients, material counting and patient’s status when leaving the OR. The duplication of information in the 3 softwares leads to time waste and may conduct to losses of information and errors. Considering this, the existence of a single software would help to increase efficiency.

5.2. Flaw Points and proposed solutions

With process mapping and resources specification, the flaw points in the current process are identified and listed by subprocess – preoperative, intraoperative and postoperative. This flaw points identification is performed based on observations of day-to-day operations and corresponds to step 2 of the methodology. With its knowledge, solutions to overcome the identified points are proposed. Resorting on discussions, both identification of flaw points and recommendation proposals involve the professionals to its development.

Lack of performance monitoring is a common flaw point throughout the perioperative process, namely the lack of indicators which are visible to all professionals in the process. Therefore, to overcome this flaw point and to be possible to evaluate the future work of COT, performance indicators are proposed in this dissertation (section 5.3.1).

5.2.1. Preoperative Process

Preoperative process is vast and consequently several flaw points can be identified based on its activities, as shown in Table 22.

Table 22: Flaw points identified, the origin and proposed solutions in the preoperative process.

FLAW POINTS	ORIGIN	PROPOSED SOLUTIONS
Lack of surgical proposal.	Lack of submission by the surgeon; Validity of the surgical proposal expired;	
Lack of anesthesiologist and planning to perform anesthesia consultation.	lack of contracted professionals; absences and lags of the doctors. Capacity and planning problems;	Digital anesthesia consultation.
Lack of exams.	Inexistence of exams; Patient do not take the exams; Exams not valid.	Phone call on the previous day to internment to confirm exams.
Lack of beds for internment.	Maladjustment of capacity to the demand; Demand's bad planning; Maladjusted planning; Lack of an integrated planning of process: Lack of pre and post clinical structure.	Integrated management of patients. Efficient bed planning.
Transportation of the patient to OT.	Lack of professionals; Unknown location of patient; Delay on patient's preparation; Lack of communication.	Flexible schedule to professionals.

The first flaw point to address is the lack of surgical proposal in the system when the patient arrives at the OT. The inexistence of surgical proposal influences the preoperative process once the related activity – Surgical Proposal – is not accomplished, which is not identified until the surgical case planning for each OR is performed. There is a lack of control of the surgical proposal in the steps prior to the surgery despite the identification of the lack of surgical proposal in the surgical case planning. Then the surgical case plan is performed, there is a specific field for the surgical proposal where is identified is lack. The lack of an actual surgical proposal submitted in the system before surgery can be considered as missing documentation and it is also identified in the literature by Aaronson *et al.* [26], Franklin *et al.* [28] and Warner *et al.* [30]. The lack of surgical proposal can be due to the lack of submission by the surgeon or surgical proposal validity expiration - which is not identified in the literature, this may be due to diagnosis' errors, errors in the proposal, the modification of surgical conditions due to changes in the patient's health state.

Following the patient pathway, the next flaw point is related with the anesthesia consultation. The lack of anesthesiologists and the anesthesiologists' planning do not allow the access to anesthesia consultations to all patients leaving a gap in process compliance of the "Anesthesia Consultation" activity. In the causes of inefficiencies identified in the literature review (chapter 3), there is no direct connection with the lack of personnel due to not having contracted professionals but it is due to absences [23], lags of doctors [27] and no time available to evaluate the patient [28]. In COT's case and to rectify this lack of capacity and planning problems, the patient is seen more carefully by the anesthesiologist during internment – "Confirmation of patient's data" activity of the preoperative process - or, in certain cases, the surgeon contacts the anesthesiologist to speed up the process and release the patient for surgery. When patient clearance is not possible before surgery and the patient's health state allows, the surgery is postponed and rescheduled. Otherwise, the patient is submitted to surgery without being seen by the anesthesiologist in the Anesthesia Consultation. To overcome this flaw point, it is proposed the existence of an effective and optimized consultation plan and a digital anesthesia consultation. This digital consultation would help to collect the maximum patient's information possible and turn the internment process more agile. This streamlining would reduce the lack of patient's information before anesthesiologist's visits in the internment. To overcome the new data protection policy, the collection of patients' data must be well controlled which may pass by not asking direct information to the patient, like the name, but asking the last 3 digits of the health number which identify them and the birthday date. This data can be quickly crossed with the existent patient data in the hospital and consequently the patient is identified in the hospital but not by a regular person.

Before internment, two situations are identified: the lack of exams, an inefficiency also identified in the literature by Aaronson *et al.* [26], Franklin *et al.* [28] and DeGirolamo *et al.* [28]; and the lack of beds in the wards to the internment – also highlighted by Kuhl [28], Zhang *et al.* [30] and Criddle *et al.* [31]. Considering the lack of beds for internment, this influences directly the time for patient's internment knowing that it is performed preferentially in the surgery's previous day. This lack of beds may reflect: 1) maladjustment of capacity to the demand; 2) demand's bad planning; 3) maladjusted planning; 4) lack of integrated planning of processes. The reasons 1 to 3 may lead to variability which reflect lack of resources during demand peaks. Both cases, misallocation and lack of beds, are identified in the literature by Kuhl [23], Zhang *et al.* [30] and Criddle *et al.* [31] as being a cause of delays in the system. There is also the case of absence of pre-clinical and post-clinical structure which influence bed capacity. In the case of lack of pre-clinical structure, it arises from improper patient internment before surgery since it is not required; in the post-clinical structure, there are cases of patients who are not discharged since there is no responsible person (e.g. family) to pick the patient from the hospital (social internments). For this latter case, an integrated management of patient and social approach may be applied by increasing the control to these cases and move the patient to an adequate recovery facility. To the bed planning problem, it is possible to redesign bed management by reallocating the beds to each department and adjust the number of beds to the real demand in each ward.

The lack of exams has a critical impact in the downstream activities of the process since it may require the postponement and rescheduling of the surgery. Kuhl [23], Franklin *et al.* [28] and DeGirolamo *et al.* [28] identified also the lack and time-consuming exams as a cause to system's malfunction. The lack of exams may be due to the patient – (s)he did not perfom the exams – or to the staff - the unproper exams that the patient has which are not adjusted to the pathology. In addition, the patient may not take the exams to the hospital on the internments' day and they are also not acessible in the informatic system for the anesthesiologist and surgeons to confirm the required data; or its lack of validity since the exams were performed long ago. To overcome this flaw point, a phone call to the patient by the service administrative on internment's previous day can be performed although it is already used in small scale. With the increase of this practice, a larger number of patients would be reminded to bring the exams and the confirmation of the existence of all exams can be performed reducing the number of patients without exams on internment's day.

After internment, the transport to OT is required so the process may continue. Therefore, an efficient transport system – namely the availability of operational assistants or patient related aspects – is required. In the literature, the causes for transportation's related inefficiencies are missing or redundant documentation for transfers as addressed by Aaronson *et al.* [26], Franklin *et al.* [28], Warner *et al.* [30] and Damle *et al.* [27]. Nowadays, there is a lack of operational assistants in the OT – total number of 28 operational assistants when there is required 48 (section 2.2.2.5, Equation 3). This reflects on the lack of available operational assistants to transport patients to OT since these professionals are not exclusively allocated to this activity. In addition, the transportation system may be influenced by unknown location of the patient (when not in the service's unit), delays in the patient's preparation by the service that sends the patient, and lack of communication between the specialty service and the OR. With this unavailability for immediate transportation, delays on the following activities are inevitable since a late arrival of patient may reflect the compliance of the surgical schedule. Since the operational assistants are the most required staff to patient's transportation, a flexible schedule which considers the demand peaks can be performed. This would help to balance the number of professionals with the overflow periods. Nowadays, the schedule is performed having into consideration the number of professionals available and the satisfaction of the requirements of each OT since there is a visible lack of professionals.

5.2.2. Intraoperative Process

The transportation problems of the preoperative process impact on the late arrival of the patient to OT and in the beginning of the intraoperative process. Several inefficiencies are highlighted within this process and can be associated with planning or operations (Table 23). In some cases, the inefficiency may be a result of an inefficiency identified in the preoperative process or be common to the other subprocesses, as is the case of transportation to the OT.

Table 23: Flaw points identified in the intraoperative process.

FLAW POINTS	ORIGIN	PROPOSED SOLUTIONS
Transportation to and from the OT;	Lack of professionals; Unknown location of professionals; Delay on patient's preparation; Lack of communication.	Flexible schedule to professionals.
Anesthesia delays.	Patients do not have the surgical consent signed.	Verify the consent during internment;
	Lack of preparation and standard supplies; Refill the cart during surgical time.	Supplies planning; Definition of OR material's quantities.
	Patient requirement of more careful care.	Intensive study of patient to predict complications.
Surgical delays.	Surgeons' delays (personal delays, improper occupations, overlapping activities).	Surgeon's scheduling considering all constrains.
	Bad surgical planning (do not consider anesthesia and cleaning times, surgeon's experience); Compliance to schedule.	Standardize borders to surgical duration on the surgical case scheduling.
	Materials' preparation and availability.	Standard materials' list; Definition of OR material's quantities.
	OR normalization.	Definition of OR material's quantities; Standardize OR layout.
	Maladjustment of post operatory beds.	Efficient bed planning.

In this process, there are critical activities that may be considered as the anesthesia and the surgery. Both activities reflect on the patient's welfare, so inefficiencies in these activities may reflect on the outcome. Despite the criticality of this subprocess, it presents most of the identified flaw points in the perioperative process, and they are most related with the lack of an efficient planning. Considering anesthesia delays, they are induced by the lack of patient's signed consent – also identified by Krvavac *et al.* [24] and Warner *et al.* [30] -, which lead to the requirement of postponing the surgery until the surgeon arrives and the patient signs the consent. The lack of patient consent is verified during patient's preparation to anesthesia – "Patient preparation to anesthesia" activity – and it is performed by the anesthesiologist, anesthesia nurse or circulant nurse. This can be overtaken by verifying patient's consent for surgery during internment (Marsh *et al.* [42]) which would allow to modify the cases order and perform surgery on other patient while the responsible surgeon informs the patient and he/she signs the consent. Moreover, the need of refilling the anesthesia cart – the cart which have the anesthesia supplies such as medicines -, by the anesthesia nurse, influences the anesthesia induction time since the nurse is not completing this task on time. This flaw point may be related with the identified lack of preparation and standard supplies by Aaronson *et al.* [25], the inadequate material storage by Bayramzadeh *et al.* [38] and the disorganized storage of instruments by Joseph *et al.* [37]. Therefore, a careful plan to order the medicines from the hospital pharmacy and the right definition of quantities may help to overcome the identified flaw point. In addition, during the patient's waking up – "Administer patient's medication and wake him/her up" activity -, the requirement of more medicines and the consequent wait and monitoring to verify the effect, may lead to delays. This influences the downstream activities, and it may be a result of patient's health state alteration and therefore the initial therapeutic is not inadequate, requiring the adjustment of the therapeutic on the moment and consequent alteration of the anesthesia plan. This problem does not have an engineering solution, but only requires a more carefully study of the patient by the anesthesiologist to predict the possible complications.

Considering the surgical delays – influencing "Surgery" activity of the intraoperative process – the causes maybe related with surgeon's delays, material preparation and availability, surgical complications and not compliance to the surgical scheduled time. Surgeon's delays may come from normal personal delays and improper occupations (e.g. coffee pauses), unexpected specialty's service meeting booked to the beginning of the day – may coincide with the scheduled surgical time – and specialty's rounds to follow up the patients as also identified by Warner *et al.* [29]. To overcome these overlapping activities, a schedule considering all the surgeons constraints must be developed to eliminate the assignment of the surgeon to an early surgery when (s)he is required on the morning rounds or even specialty meetings (Aaronson *et al.* [26]). In addition, surgical delays, which influence downstream activities, may come from bad surgical planning. Most of the plans do not consider anesthetic time, OR cleaning and disinfection, and surgeon's experience – the existence of interns in the surgery team leads to more pauses to teach. In addition, surgical complications may also lead to delays on the plan. Considering this flaw point, the definition and standardization of durations to consider on the surgical plan must be performed. This surgical plan must consider anesthesia duration and OR cleaning in addition to the surgical duration.

Regarding the surgery delays due to material preparation and availability, there are several causes that can be addressed. First, the lack of material's planning, namely the material is not planned for surgery but is prepared based on the nurses's knowledge – without any list– and introduced in the OR during anesthesia induction. This inefficiency is also identified by Aaronson *et al.* [25] and Copenhaver *et al.* [35]. The design of a standard material list to consider the basic procedure material and another list to each surgery type would help to guide the nurses during material preparation. Consequently, the effects of not preparing the material in advance would be reduced. Moreover, the material present and stored in the OR (e.g. sutures) has not defined quantities – there is no defined inventory level -, which leads to unnecessary exits from the OR by the nurses to get material or a special request not communicated by the surgeon in advance. The lack of defined quantities may be overcome by application of an inventory management policy and consequently implementation of defined quantities in the OR – standardize the OR quantities. Related solutions regarding material are suggested by Aaronson *et al.* [26], Dyas *et al.* [37], Copenhaver *et al.* [36] and Avansino *et al.* [35]. This would reduce the absence of the circulating and anesthesia nurse from the OR to collect the material and refill the supplies.

In addition to the referred inefficiencies, the lack of room normalization can also provide delays in intraoperative activities. Each OR is organized according to the preferences of the professionals which lead to inadequate storage as mentioned by Bayramzadeh *et al.* [38], unnecessary steps in the different team members' circuits and increase of operational time and OR congestion [38]. This lack of normalization also on the material quantities leads also to the increase of operational time due to the requirement of refilling the material during the surgical procedure, as mentioned previously. The solution to apply is the same as in the previous paragraph.

As for the unavailability of beds for internment in the preoperative process, there is a maladjustment of beds' demand to receive the patient in the postoperative units, which influence the "patient's transference to postoperative unit" activity. This may lead to the requirement of the patient to wait in OT's interchange area which may influence activities in the intraoperative process – e.g. the following patient cannot be prepared due to the presence of another person in the room. The solution to this case is the same presented in the preoperative, a bed management which can reallocate the beds according to the needs – efficient bed planning (Balssarre *et al.* [33] and Kuhl [24]).

Regarding communication, the use of 3 different and non-integrated softwares during surgery and its informatic problems lead to delays like the confirmation of materials used during surgery and losses of time during patient waking up since it is necessary to replicate the information. This could be overcome by a centralized information system as mentioned by Baldassarre *et al.* [32].

5.2.3. Postoperative Process

Postoperative flaw points (Table 24) are much related with the flaw points presented in the previous parts of the process – preoperative and intraoperative -, namely the lack of availability of the surgeon and transportation problems.

Transportation problems are not going to be addressed again since they have already been described in section 5.2.1and a solution proposed. The lack of surgeon's availability has a direct impact on patients discharge and consequently the downstream activities of other patients – internment – as accessed by

Zhang *et al.* [31]. In addition, the post clinical structure referred on the preoperative process' flaw points is a cause for discharge delays - patients are not discharged since there is no responsible person (e.g. family) to pick the patient from the hospital (social internments). An integrated management of patient and social approach may be applied by increasing the control to these cases and move the patient to an adequate recovery facility. To the surgeon's availability, the definition of more discharge periods in their schedule would help to reduce the unnecessary and incorrect occupation of beds.

Table 24: Flaw points, the origins and proposed solutions identified in the postoperative process.

FLAW POINTS	ORIGIN	PROPOSED SOLUTIONS
Transportation to post operatory units.	Lack of professionals; Delay on patient's preparation; Lack of communication.	Flexible schedule to professionals.
Discharge delays.	Availability of surgeons to discharge the patient;	Introduce more discharge periods on surgeon's schedule.
	Post clinical structure.	Integrative management of patient.

5.3. Solutions' Development

In section 5.2, the flaw points are identified, and solutions are proposed. The aim of this section is to further develop 2 solutions from the ones identified in the previous section. The selection of this flaw points are performed by this dissertation's author and discussed with the COT's professionals to access their perspective about the possible impact. This is the base of future implementation of these solutions at COT.

The 2 solutions selected to further developments are: 1) proposal of intraoperative indicators, and 2) the tool for OR scheduling and material planning – with the application to the compresses as an example. The chosen solutions are the ones considered of most impact in a short period of time, so the care provided may quickly improve as well as the satisfaction of both patient and staff.

This section is thus divided in 2 subsections which address and discuss each solution separately starting by the intraoperative indicators and then the tool's development.

5.3.1. Intraoperative Indicators

Considering the intraoperative process and its criticality, there is a need to define measures to system's evaluation. These measures are based on the literature review (chapter 3) and the requirements identified through the flaw points (section 5.1). The indicators proposed are only for the intraoperative process due to its importance to monitor this subprocess and the large number of identified flaw points.

The indicators are based on 6 classes– quality, complexity, occupation, cancellation, time and satisfaction -, and have different objectives within each category. Moreover, the guidelines on the report of *Avaliação da Situação Nacional dos Blocos Operatórios [7]* are followed and thus all the categories in the report that evaluate the current situation of national OTs are considered. Table 25 summarizes the proposed indicators. With the use of these indicators, the evaluation of the process can be performed as well as an accurate tracking of the system and problems leading to quicker responses to system' alterations. Based on this, efficiency improvement is expected since the professionals can have a better perspective of their performance. Additionally, if the indicator results become public, it can alert the professionals and increase a healthy competition to improve result between the different specialties.

First, quality indicators are addressed since this class is important to the care receiver – patient – and the care providers – hospital. The daily compliance to the scheduled surgical plan evaluates the number of surgeries performed which are planned for that specific day. This indicator is calculated by making the ratio between the number of surgeries in the plan performed and the number of surgeries planned (Equation 4). With this indicator, an alert for the process and planning causes of not accomplishing the surgical plan can be sent since a low value of this indicator demonstrates problems within the system – e.g. bad planning of the surgical duration. Considering the bad planning surgical accuracy and since it is one of the identified flaw points, it may be measured by the case duration accuracy indicator which is calculated by performing the ratio between the number of surgeries performed on time and the number of planned surgeries (Equation 5).

$$\%\ of\ daily\ compliance\ to\ the\ scheduled\ surgical\ plan = \frac{number\ of\ planned\ surgeries\ perfomed}{number\ of\ planned\ surgeries} \times 100$$

Equation 4: Formulation to calculate the percentage of daily compliance to the scheduled surgical plan.

$$Case\ duration\ accuracy = \frac{number\ of\ surgeries\ performed\ on\ time}{number\ of\ planned\ surgeries}$$

Equation 5: Formulation to calculate the case duration accuracy.

One of the identified flaw points in the intraoperative process is the lack of surgical consent signed by the patient. With this, the monitorization on this flaw point is required and can be performed with the use of the percentage (%) of patients with signed surgical consent before entering the OR. This indicator would help to visualize the lack of surgical consents signed before the patient arrives at the OT and more specifically to the OR (Equation 6). A low value would reflect a compliance to the signed surgical consent which reflects on a reduction of time during the OR activities, so the patient can be informed and be required to sign the required document. In addition to these quality indicators, the percentage of first cases on-time can be added by calculating the ratio of first cases' surgeries performed on time and the number of first cases (Equation 7).

$$\%\ of\ patients\ with\ signed\ surgical\ consent\ before\ entering\ the\ OR = \frac{number\ of\ patients\ with\ signed\ surgical\ consent\ in\ the\ OR}{number\ of\ performed\ surgeries} \times 100$$

Equation 6: Formulation to calculate the percentage of patients with signed surgical consent before entering the OR.

$$\% \; of \; first \; cases \; on - time = \frac{number \; of \; first \; cases \; on - time}{number \; of \; first \; cases} \times 100$$

Equation 7: Formulation to calculate the percentage of first cases on-time.

Complexity indicators aim to measure the complexity of the system. This complexity may be measured by the number of different resources used during the intraoperative process. This indicator is difficult to operationalize since it requires the constant record of instruments, which is not performed nowadays by the medical staff. Despite this, it is possible to apply this indicator to the instruments which require a special record in the system – e.g. prostheses. The availability of instruments aims to evaluate the required instruments that are available to be used on surgery and it is calculated by performing the ratio between the number of instruments used and the number of instruments required. The number of instruments used must not consider the instruments used to remediate the lack of certain instruments since these instruments are not the ones required initially. Its consideration may lead to a misunderstanding of this indicator since the indicator output is higher and does not reflect the inexistence of the required instrument (Equation 8).

$$availability \; of \; instruments = \frac{number \; of \; instruments \; used}{number \; of \; instruments \; required}$$

Equation 8: Formulation to calculate the availability of instruments.

OR occupancy level (Equation 9) is an important indicator to verify the utilization rate of an important and costly resource. The OR is one of the main resources in the intraoperative process and without it the surgery cannot be performed. Therefore, the measure of its occupancy would help to identify the percentage of time in which the OR is used to perform surgery and anesthesia.

$$OR \; occupancy \; level = \frac{number \; of \; hours \; used \; of \; surgical \; activity}{number \; of \; OR \; available \; hours}$$

Equation 9: Formulation to calculate the OR occupancy level.

Other resources are used in the process, so it is also important to measure the percentage of other resources utilization. The resources to measure should be the ones which are considered more critical due to its influence in the downstream activities, such as beds. For this indicator, a ratio between the required number of resources and the available number of resources must be calculated (Equation 10). The use of the percentage of resources utilization help to assess which of the resources need to have their planning and allocation reviewed or even the need to increase the number of available resources.

$$\% \; of \; resources \; utilization = \frac{available \; number \; of \; resources}{required \; number \; of \; resources} \times 100$$

Equation 10: Formulation to calculate the percentage of other resources utilization.

Cancellations must also be seen by the patient and the hospital's perspective. For both, cancellations may be a sign of an inefficient service and reflect on an emotional wear of both professionals and patients. Therefore, it is a class that must be analyzed as carefully as possible. The percentage of cancelled surgeries may reflect 2 things: 1) inefficiency of the system as a result of bad planning; and/or 2) lack of resources as material. This indicator is calculated by dividing the number of surgeries not performed by the number of planned surgeries (Equation 11). It can also be considered a quality indicator since it also reflects the compliance to the surgical plan which is considered an indicator.

$$\%\ of\ cancelled\ surgeries = \frac{number\ of\ surgeries\ not\ performed}{number\ of\ planned\ surgeries} \times 100$$

Equation 11: Formulation to calculate the number of cancelled surgeries.

The surgery delays are considered flaw points with origins in patient and medical team delays. Measuring these 2 origins can be performed by 2 indicators: percentage (%) of delayed procedures due to patient’s delays (Equation 12) and the percentage (%) of delayed procedures due to medical team delays (Equation 13).

$$\%\ of\ delayed\ procedures\ due\ to\ patient's\ delays = \frac{number\ of\ delayed\ procedures\ due\ to\ patient's\ delays}{number\ of\ delayed\ surgeries} \times 100$$

Equation 12: Formulation to calculate the percentage of delayed procedures due to patient's delays.

$$\%\ of\ delayed\ procedures\ due\ to\ medical\ team's\ delays = \frac{number\ of\ delayed\ procedures\ due\ to\ medical\ team's\ delays}{number\ of\ delayed\ surgeries} \times 100$$

Equation 13: Formulation to calculate the percentage of delayed procedures due to medical team's delays.

Table 25: Definition of the proposed indicators class.

Class	Indicators
Quality	• % of daily compliance to the scheduled surgical plan; • Case duration accuracy; • % of first cases on-time; • % of patients with signed surgical consent before entering the OR.
Complexity	• Number of different resources used; • Availability of instruments;
Occupation	• OR occupancy level; • % of other resources utilization.
Cancellations	• % of cancelled surgeries; • % of delayed procedures due to patient’s delays; • % of delayed procedures due to medical team delays;
Time	• % of idle time; • % of overtime; • Average patient time in the OT; • Average delay for cases not on-time; • Average OR preparation time.
Satisfaction	• Patient-reported outcomes; • Medical team complaints.

The evaluation of processes using time records is common so time indicators are defined to be applied in the intraoperative process. The first indicator is the idle time which considers the time in which there is no added value to the process as it is the time in which the OR is unused. This indicator can be defined by the ratio of the used time for non-valuable activities and the OR number of working hours (Equation 14).

$$\%\ of\ iddle\ time = \frac{OR\ unused\ hours}{number\ of\ OR\ available\ hours} \times 100$$

Equation 14: Formulation to calculate the percentage of iddle time.

The non-value time in the OR is important to measure but it is also important to consider the extra working hours – overtime. This indicator – percentage (%) of overtime – can be calculated by the ratio of OR working hours and the OR planned working hours (Equation 15). In addition, the average OR preparation time is also considered to evaluate the system since one of the identified flaw points is the lack of material preparation, therefore its measure would help to see how this affects the planned schedule.

$$\%\ of\ overtime = \frac{OR\ working\ hours}{OR\ planned\ working\ hours} \times 100$$

Equation 15: Formulation to calculate the percentage of overtime.

The time a patient stays in the OT is important to measure based on the surgery type, since there are pathologies which require a longer length of stay in the intraoperative process. If this indicator shows high values when compared with the average time for the corresponding pathology, it is required to evaluate what are the causes for that to happen – e.g. long waiting time for the room to be prepared. In addition to this, the average delay for cases not on-time influences the patient's satisfaction and the intraoperative process' functioning once it delays the remaining planned surgeries for the day.

Satisfaction is an important aspect to consider when talking about systems. In COT's case, patients and medical staff must be satisfied so satisfaction aligned with emotional stability help to perform process' activities. Therefore, 2 indicators are defined: Patient-reported outcomes – which aim to evaluate the patient's satisfaction – and medical team complaints – which aim to evaluate the satisfaction of the medical professionals and warn the administrations to possible problems in the system. This problem identification can be useful since the medical teams are the ones in the field every day and have the most knowledge about the system. In addition, the medical team complaints are of most importance since these stakeholders may influence the efficiency of the process – e.g. performing strikes to show their dissatisfaction.

5.3.2. Tool for OR scheduling and material's planning

As mentioned in section 5.2, one of the intraoperative flaw points is on the surgical duration planning – which does not consider the anesthesia duration – and lack of material's planning for surgery - which requires refilling working materials in the OR during surgery. Each operating room is organized by the medical team leading to unnecessary steps in the different team members' circuits and increasing operational time. In addition, the need to refill the supplies during surgery forces the absence of team members in the room during the surgical period and consequently the accumulation of tasks by the remaining nurse – anesthesia or circulant.

Herewith, to assess the circuits in each OR and evaluate the impact of not performing a proper material plan, as it is a flaw point identified, Spaghetti Diagrams are drawn. These diagrams may be seen in Figure 19 and Figure 20, as well as in the appendix (Figure 26 to Figure 31). These Spaghetti Diagrams only consider the circulant nurse, anesthesia nurse and the anesthesiologist since these are the members of the surgery team that perform more movements in the OR. The surgeons and instrument nurse's movements are excluded because they remain in the same place during most surgical time (they may move only for e.g. a more specific patient positioning which requires the surgeons' help).

The Spaghetti diagrams are performed considering the period between the entrance and departure of the patient in and from the OR, once it is the time in which the patient is in the OR – considered a critical resource – and performs the surgery and the anesthesia activities – these activities are considered crucial for the patient's treatment.

Each specialty, including the urgent surgeries, were observed 3 for days and the Spaghetti Diagrams from surgeries of those 3 days were performed, resulting in a total of 28 Spaghetti Diagrams. Considering these diagrams (e.g. Figure 19 and Figure 20), it is possible to see the large number of movements made by the medical professionals within the OR. Both anesthesia and circulating nurses perform a large amount of movements and it is visible many entrances and departures from the OR.

The movements regarding the entrance/departure of the OR are related with the requirement of replenishment of supplies or the rest periods of the professional. Considering the supplies requirement, since there is no material's planning and defined quantities of supplies there is the need of refilling the supplies sometimes during surgery, consequently there is waste of time.

The Spaghetti Diagrams show the large number of movements – lines – in specific zones, depending on the health professional. The circulant nurse (Figure 19) presents the major number of movements near the supplies' storage in the OR. Despite this, this nurse presents also movements to leave the OR and to the anesthesia zone – anesthesia cart. Considering the anesthesiologist, (s)he has movements on the anesthesia zone, namely the monitoring material and the anesthesia card. Like the anesthesiologist, there is the anesthesia nurse whose major movements are near the patient and the anesthesia cart. Moreover, this nurse also has movements in the supplies' storage zone to get the required material.

The Spaghetti Diagram allows to conclude that there is a large number of movements within the OR by the health professionals. This movements need to be reduced since they highlight waste in time and value of the activities performed within the OR – e.g. to get supplies not planned and not available in the OR. Therefore, it is developed a tool which allows OR scheduling according to each surgery type and specialty, and to define the quantities of each supply to have in the OR to fulfill the daily demand based on the OR schedule.

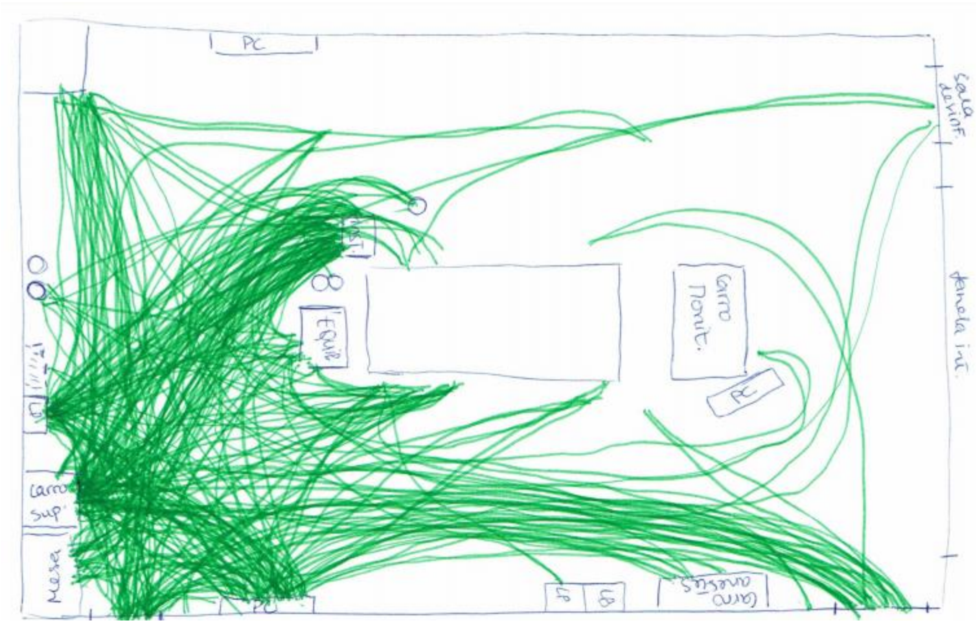

Figure 19: Spaghetti Diagram of the Circulat Nurse's circuit, in OT4.

Figure 20: Spaghetti Diagram of Anesthesiologist (orange) and Anesthetist Nurse's (blue) circuit, in OT4.

The objective of this tool must be firstly defined – a user-friendly tool to provide support for the specialties in surgery's scheduling and material planning, which reflects directly on the efficiency of the system. The tool is developed in Microsoft Excel, so the professionals can use it without requiring an extra program in their computer and since this program can be considered easy to use by administratives and doctors responsible for OR scheduling since they already use it for OR and staff scheduling. In addition, the excel sheets are in Portuguese so the user can have a direct association to its language (this is particularly important regarding the name of the procedures).

Considering the objectives, data from the surgical duration must be collected from CPCHS Software to reduce the observations on sight. The data from surgical durations considers all the surgeries performed in all OTs from COT in the period from March and April of 2018, resulting in a total of 1239 surgeries from different specialties. This data is structured in specialty, surgery and times – arrival at OR, entrance in OR, beginning of anesthesia, beginning of surgery, end of surgery, end of anesthesia, exit of OR, exit of OT – as may be seen in Table 26. In this stage, all specialties are considered, even the ones that are not part of COT, since they are also performed on emergency OT (OT4).

This data is treated – specialties that are not from COT are not considered – resulting in a total of 274 surgeries' data considered. Based on these surgeries, the average time of each surgery, considering the specialty, is calculated to provide a base for the tool (Table 27). The average time of surgery considers the anesthesia duration, the surgical duration and an estimate cleaning time of 25 minutes for the OR, although the tool does not consider the anesthesiologist and the surgeon that performs the surgery and the type of surgery in the cleaning time. These factors must be considered in a future work, since they influence the surgical duration and the OR occupancy time (indicator defined in section 5.3.1).

Table 26: Sample of the data for solution's development.

Specialty	**Surgery**	**Arrival at OT**	**Arrival at OR**	**Beginning of anesthesia**	**Beginning of surgery**	**End of surgery**	**End of anesthesia**	**Exit of OR**	**Exit of OT**
Cirurgia Geral (U. Internamento)	Ablacao do Endometrio	8:09	8:39	8:45	9:58	12:10	12:12	12:12:	12:14
Cirurgia Geral (U. Internamento)	Actos de Diagnostico no Intestino Delgado	8:05	8:15	8:20	9:32	12:25	12:44	12:48	13:00
Urologia (U. Internamento)	Adrenalectomia Bilateral	8:05	9:16	9:16	10:27	11:27	11:35	11:36	11:41
Estomatologia	Alveoloplastia	8:50	9:40	9:48	10:32	10:40	11:03	11:03	11:05
Cirurgia Geral (U. Internamento)	Amputação de dedo do pé	11:17	11:27	11:27	12:20	13:13	13:25	13:25	13:30

It is possible to verify (Table 27) that there are no surgeries' type with statistical representation of the durations, since the sample of data is from a short period of time. Therefore, it is required a large amount of data to provide an accurate median duration of the surgery.

Table 27: Sample of the data of each surgery.

Specialty	**Surgery**	**Average Duration (hours)**	**Minimum Duration (hours)**	**Maximum Duration (hours)**	**Number of surgeries performed**
Cirurgia Geral (U. Internamento)	ABLACAO DO ENDOMETRIO	03:58:00	03:58:00	03:58:00	1
Cirurgia Geral (U. Internamento)	ACTOS DE DIAGNOSTICO NO INTESTINO DELGADO	04:58:00	04:58:00	04:58:00	1
Urologia (U. Internamento)	ADRENALECTOMIA BILATERAL	02:45:00	02:45:00	02:45:00	1
Estomatolog	ALVEOLOPLASTIA	01:40:00	01:40:00	01:40:00	1
Cirurgia Geral (U. Internamento)	AMPUTACAO DE DEDO DO PE	01:54:17	01:37:00	02:23:00	7
Cirurgia Vascular (U. Internamento)	AMPUTACAO DE DEDO DO PE	02:02:37	01:19:00	2:59:00	8
Cirurgia Geral (U. Internamento)	AMPUTACAO DO MEMBRO INFERIOR ACIMA DO JOELHO	03:00:00	02:16:00	03:43:00	8
Cirurgia Geral (U. Internamento)	COLECISTECTOMIA LAPAROSCOPICA	02:27:48	01:09:00	05:45:00	49
Cirurgia Vascular (U. Internamento)	ANGIOPLASTIA DE VASO(S) NAO CORONARIO(S) NCOP	03:38:49	01:40:00	07:40:00	40

After treating the data, the development of the tool is started. The aim of this tool is to help the scheduling of the OR since the occupation is more accurate when compared with the actual scheduling – the present surgical duration does not consider aspects like anesthesia and this new tool does.

Additionally, in the tool, it is created one excel sheet for each week day, so the scheduling can be performed independently and there is no misunderstanding of the week day which it refers to. The week day is identified, as well as the different columns which correspond to specialty, surgery, duration and the number of compresses. Moreover, the maximum activity duration of the OR is identified as being the 12h which is provided by the COT timetable as being the available working hours; and a error margin is defined as being 2h. This can be seen in Figure 21.

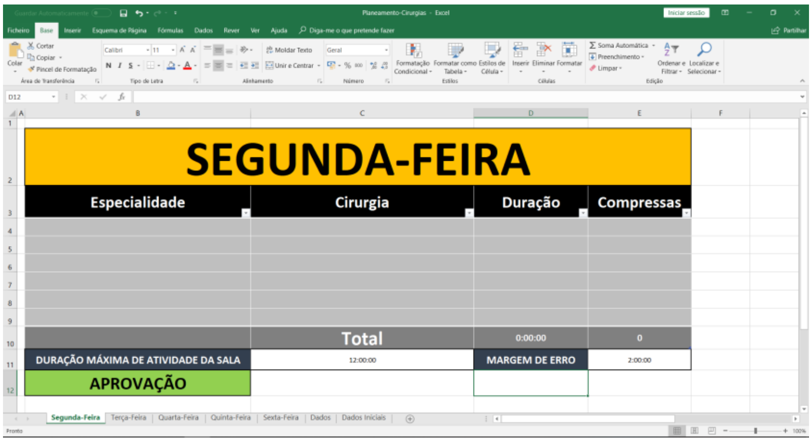

Figure 21: Example of the tool for Monday.

In the first column, the specialty's surgery is considered. The user can choose from one of four options that reflect the surgical specialties that operate in COT's facilities, namely the general surgery, orthopedics, urology and vascular surgery (Figure 22). This tool is not created based on the block scheduling used on the master surgery schedule of COT – each specialty has a specific OR – since if the director decides to change to open schedule, the tool is also valid.

Then, within the chosen specialty and in column 2, the surgery is selected, and this can only be performed if the specialty is first chosen (Figure 23). In this list, it is only considered the surgeries performed within the data period mentioned above. Once again, it is important to mention that the surgery's names are in Portuguese, so the user can associate it directly to the requirements.

After selecting the surgery, the duration of the associated OR occupation automatically appears in the table – column 3, "*Duração*" - and, when there is available information, the required number of specific materials would also appear – column 4 (Figure 24). In this case, the 4th column refers to the average number of compresses required for that surgery which can be accessed through the record in the CPCHS' software performed to each surgery. This column has no value due to the lack of data although it is introduced to exemplify its use.

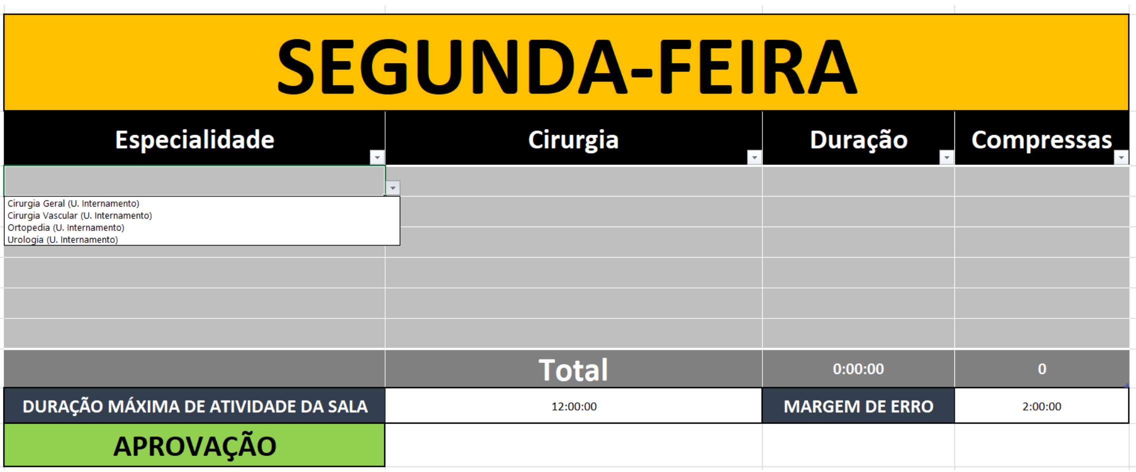

Figure 22: Specialties which can be chosen in the tool.

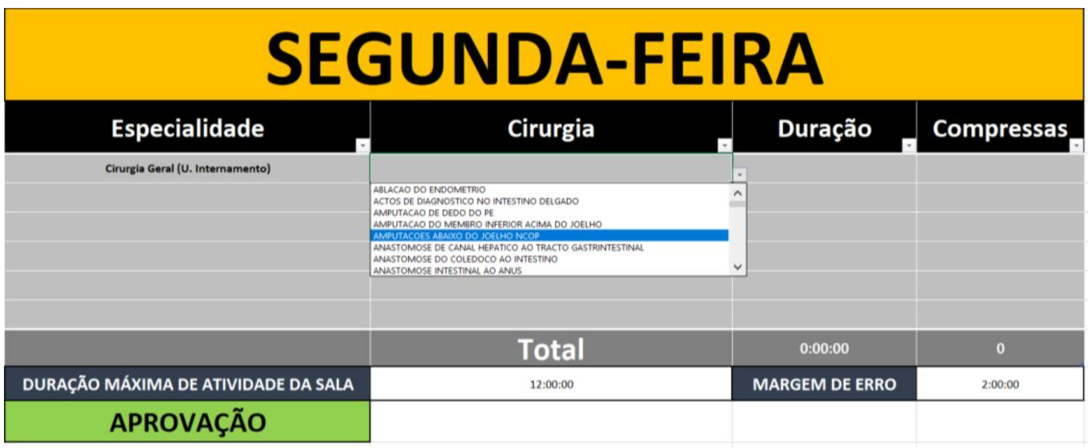

Figure 23: Selection of the surgery to perform.

SEGUNDA-FEIRA			
Especialidade	**Cirurgia**	**Duração**	**Compressas**
Cirurgia Geral (U. Internamento)	ABLACAO DO ENDOMETRIO	3:58:00	
	Total	3:58:00	0
DURAÇÃO MÁXIMA DE ATIVIDADE DA SALA	12:00:00	**MARGEM DE ERRO**	2:00:00
APROVAÇÃO			

Figure 24: Duration associated with the surgery.

With this process, the surgical day can be more easily and effectively planned, and the total occupation time of the OR is calculated as can be seen in the Total line (Figure 25). To not exceed the OR maximum activity duration – 12h –, a cell with the approval of the plan is created. This cell considers the sum of the total scheduled duration and compares it with the maximum available duration. With this, the cell returns a traffic light color, so the user can be alerted if the scheduling hours are under, equal or over the available hours - from 0 to 10h scheduled hours, the "*Aprovação*" cell returns the green color; from 10 to 12h, it returns the yellow color; and over 12h, the cell returns the red color. The error margin is introduced so the user can have a margin of error for scheduling. In this first version, the error margin is introduced and should be defined by the user, so it can work as a "safety net" if complications with patients happen. In addition, this error margin is introduced to overcome the lack of detailed in this tool's version since the anesthesiologist and surgeon responsible for the surgery is not considered in this phase. As a future work and tool's improvement, the surgery's anesthesiologist and surgeon should be considered since they influence all durations.

SEGUNDA-FEIRA			
Especialidade	**Cirurgia**	**Duração**	**Compressas**
Cirurgia Geral (U. Internamento)	ABLACAO DO ENDOMETRIO	3:58:00	
Cirurgia Geral (U. Internamento)	APENDICECTOMIA	2:14:45	
Cirurgia Geral (U. Internamento)	APENDICECTOMIA	2:14:45	
Cirurgia Geral (U. Internamento)	AMPUTACAO DE DEDO DO PE	1:54:17	
	Total	10:21:47	0
DURAÇÃO MÁXIMA DE ATIVIDADE DA SALA	12:00:00	**MARGEM DE ERRO**	2:00:00
APROVAÇÃO			

Figure 25: Total duration of the scheduled surgeries.

By applying this tool and after introducing the materials' quantities, it is expected to reduce the number of movements of the professionals motivated by the lack of material within the OR and the need to bring the material from outside the OR during surgery. In addition, it is expected an increase of the overall system's efficiency.

As mentioned previously, the limitation of the tool is the lack of consideration of the anesthesiologist and the surgeon on the average surgery duration. This can be considered as future work of this tool, since there is evidence that this influences the average duration of the surgery. These considerations can lead to a reduction of the required error margin since it can start to only consider the possible surgical complications because of the accuracy improvement by defining the personnel involved.

5.4. Chapter conclusions

The perioperative process is composed by 3 subprocesses – preoperative, intraoperative and postoperative.

Preoperative process starts with the patient's referral as requiring surgery and ends with the patient's transfer to the OT. In this subprocess, the consultations are of most importance to proceed to the intraoperative process since the right diagnoses of patient's pathology influences its welfare. Surgeon's and anesthesiologists are the most required human resources in this subprocess. Moreover, bed availability for internment influences the downstream activities which are the remaining subprocesses.

With patient's arrival to OT, the intraoperative process begins. All this subprocess occurs in the OT, and the OR and the surgical instruments are critical for surgery's performance – considered a critical activity within the process. Once the surgery is considered a critical activity, the surgical team is also considered critical.

The postoperative process starts with the arrival of the patient to the post operatory unit – PACU, UCI, IntCU – and finishes with patient's discharge. This process is critical for patient's recovery once the correct evaluation of the patient and redirection affects his/her health state.

With the 3 subprocesses mapped and described, it is possible to identify the flaw points within each subprocess. These flaw points are directly related with planning and the process. Several of the identified flaw points are addressed in the literature – e.g. lack of consideration of anesthesia duration in the surgical duration. In addition, there are flaw points common to all 3 subprocesses (e.g. transportation). Several solutions are proposed. Among the proposed solutions, two are selected for further development: definition of intraoperative indicators and the development of a tool in Microsoft Excel for OR scheduling and material planning. The proposed intraoperative indicators are based on the literature and adapted to analyze the process performance and improvements. Considering the 2nd solution, Spaghetti diagrams are developed to evaluate the OR circuits and consequently confirm the flaw points. With this, the identification of several absences in the OR from the nurses (except the instrument nurse) is performed. The requirement of improving materials' planning is thus confirmed and, in addition, the improvement of OR scheduling accuracy is performed with the aid of tool this tool. OR scheduling and materials' planning tool helps to overcome the need of the circulating and anesthetist nurses to leave the OR to get or refill the material required for the on-going surgery. This tool provides an expected duration of the surgery by considering the specialty, the surgery and the average duration based on the historical records of the hospital – contemplating the surgery, anesthesia and cleaning duration. Moreover, a color alert is activated when the sum of the scheduling surgeries' duration is under, equal or over the maximum OR activity duration (12h). As a future work, the implementation of this tool can be performed and the anesthesiologist and surgeon responsible for the surgery should be considered as a constraint to complement the tool.

6. Conclusions and Future Work

Healthcare is a service industry where the requirements of patients (consumers) are critical to its development and should be aligned with the organization's objectives. As part of the National Health Service, public hospitals as critical organizations in the health system require organization of processes that guarantee a sustainable performance. A sustainable performance is not only a high financial capacity, but also an efficient use of available resources while meeting the patient's needs. Towards this, critical services within the hospital should be highly organized as is the case of Operating Theatres (OTs). The surgical interventions performed, in the OTs, are the major source of admissions into a hospital. This and the large and steadily increasing surgical demand, leads to a service with large expenses but also a source of revenues, while having a very important role in the health being of patients and in the performance of many other units of the hospital. For instance, recovery rooms are downstream services and provide a monitored rehabilitation of the patient after surgery. Therefore, OTs and the respective recovery rooms are critical assets to hospitals. Moreover, the improvement of the processes in the operating theatres is critical to fulfill the requirements of *Sistema Integrado de Gestão de Inscritos para Cirurgia* (SIGIC) and reduce the waiting times of the patients, without increasing available of resources and consequently costs.

This dissertation addresses the COT of the CHLN, which is an example of a critical OT. COT's inefficiency is a major concern to the stakeholders of HSM –CHLN. Thus, this dissertation aims: 1) to understand the functioning of the organization's culture and surgical processes, 2) to map the current perioperative process, and 3) to identify existing flaw points which may lead to inefficiency.

The National Health Service presents large waiting lists for surgery. In particular, CHLN has a large waiting list, especially on orthopedics, requiring a careful study of the perioperative process in use and flaw points.

Literature in healthcare inefficiencies proposes several methodologies to reduce inefficiencies in these systems such as Lean methodologies, Graphical Methods and BPR. Most of the works in this area consider the engagement and involvement of the different stakeholders as part of the improvement process with resort to surveys, interviews and meetings. Despite this, it is visible a gap on OR indicators regarding standardization. Nevertheless, several authors contributed actively to this matter by identifying key performance indicators.

The proximity to COT's practices and everyday operations allow a deep understanding of the COT's system and a detailed mapping of the perioperative process. First, a less detailed process map is performed – macro scale – to assess the activities and gain an insight of the current practices. Then, a micro scale process is mapped, detailing all the surgical activities. Clearly, the perioperative process is complex and extensive which requires a large knowledge of the processes as well as a large support of the medical professionals to map the process. By mapping the process and considering its required understanding, both 1st and 2nd objectives of this dissertation are achieved.

The process map with additional observations in COT and the involvement of the medical professionals, allow to identify flaw points in each subprocess which results in the achievement of the 3rd dissertation's objective. There are flaw points which are common to the three subprocesses (preoperative, intraoperative and postoperative) as is the case of patient transportation. In addition, the existence of 3 softwares in the intraoperative process and 2 in the postoperative lead to duplication of information and in extreme cases may lead to errors by the staff. Moreover, the inexistence of standardized indicators to the process, as identified also in the literature review, and the lack of standardized surgical duration planning and material's planning is identified. These flaw points lead to the decision of intervening in more detail in these areas and propose solutions to the remaining flaw points.

The lack of standardized indicators to the process is the first analyzed flaw point. This is aligned with the literature. By identifying this difficulty, a set of indicators to track the intraoperative process is proposed. These indicators help to monitor the process, to identify deviations to COT's goals and consequently to alert the leadership members to the need of identifying the deviation origins and improvement. The indicators proposed are organized in 6 categories (quality, complexity, occupation, cancellation, time and satisfaction) according to the report *Avaliação da Situação Nacional dos Blocos Operatórios [7]*.

Surgical duration planning and lack of material's planning for surgery are two other flaw points selected to further study. Currently the surgical duration planning does not consider the anesthesia duration –- and the lack of materials in the OR makes the surgery longer as nurses need to leave the room to refill working materials in the OR during surgery. This intraoperative flaw point arises special interest to develop since the solution's impact is high and of short-term visibility of improvements. A tool in Microsoft Excel is developed to help the scheduling and planning of surgeries. The tool is user-friendly and allows the scheduler to select the specialty and surgery and returns the total OR occupation of the schedule and the material required to each surgery.

Despite the existence of several flaw points, the dissertation's period does not allow to develop all proposed solutions in detail as performed previously. Considering this, several solutions are proposed to COT's management. These solutions are: the digital anesthesia consultation, confirmation of exams through phone call before the patient arrives at the hospital, integrated management of patients and bed planning, adjustments of professionals' schedules to consider all constraints (e.g. morning rounds of surgeons), materials' lists for surgical material and more discharge periods in the postoperative process. Although solutions are important to achieve the objectives, it is recommended to the professionals to know not only separate parts of the process in which they are required, but every step of the process. This knowledge allows the engagement of the medical professionals enabling the professional to be alert and, to provide ideas and tools for self-improvement.

Several aspects can be further developed in the future. First and foremost, it is required the performance of methodology's step 4 – implementation – which due to the period for this dissertation's development was not possible. Then, the Excel tool might include the option to consider the anesthesiologist and the surgeon that performs the surgery to compute the surgery duration and the type of surgery to compute the cleaning time. In addition, it is recommended the qualitative evaluation of the current state of the process and the comparison with the state achieved by the implementation of the proposed and developed solutions. With this evaluation, a new assessment of the flaw points should be performed, and the solutions proposed adapted, and further and new solutions proposed. By continuously monitoring and controlling the system, as well as implementing the solutions is expected to improve COT's efficiency.

Moreover, as future work, it is the implementation of the dissertation's methodology to other specialties to access their state and consequently, if verified the same flaw points, the implementation of the OR Scheduling and material's planning tool in their services.

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Appendix

Table 28: Inefficiency causes' categories addressed by different authors.

	Arrival of patients	Exams and labs results	Documentation and consent	Emergency cases	Beds	Equipment	Instruments	Staff	Overlapping activities	Consults	Communication	OR layout
Bouamrane [23]										X		
Kuhl [24]	X	X		X	X			X				
Krvavac et al. [25]	X		X			X			X			
Aaronson et al. [26]	X		X				X			X	X	
Damle et. al [27]			X								X	
Franklin et al. [28]		X	X					X				
DeGirolamo et al. [29]		X							X			
Warner et al. [30]			X						X			
Zhang et al. [31]					X			X	X			
Criddle et al. [32]					X				X			
Baldassarre et al. [33]					X	X					X	
Palmer et. Al [34]						X					X	X
Avansino et al. [35]						X	X					
Copenhaver et al. [36]							X					
Dyas et al. [37]							X					
Joseph et. al [38]												X
Bayramzadeh et. al [39]												X
March et. al [42]									X	X		
Pugel et al. [43]											X	
Bowen et al. [44]											X	

Table 29: Indicators address by different authors in efficiency problems.

Author	Indicator
Kuhl [24]	• Waiting time for patient; • Nurse time in DOSA; • DOSA complete time; • OR time; • Completion time of last patient in DOSA; • Completion time of last patient in OR Holding; • Utilization of nurses and techs;
Bouamrane [23]	• Number of cancelled appointments; • Number of patients who did not attend appointments; • Number of patients in waiting list; • Time to wait;
Criddle et al. [32]	• Number of times a patient was delayed; • Resource utilization; • Average time of patient in the system;
Copenhaver et al. [36]	• Average number of instruments' returns peer week; • Weight per kit; • Efficacy of location of emergency cards; • Case volume;
Avansino et al. [35]	• Operative time; • Total time in OR; • Length of stay; • Supply costs; • Intraoperative complications;
Krvavac et al. [25]	• Expected arrival; • Arrival at ACU; • Arrival to suite; • Scheduled time; • Start time/scope time; • Out of room time;
Warner et al. [30]	• Percentage of first cases on-time; • Average delay for cases not on-time; • Holding unit arrival time;
DeGirolamo et al. [29]	• Time from general surgery consult initiation to completion; • Time from admission to admission to general surgery service; • Overall length of stay;

Author	Indicator
Dyas et al. [37]	• OR preparation time; • Tray weight; • Number of trays; • Number of instruments; • Turnover savings; • OR average costs;
Pugel et al. [43]	• Awareness of surgical site brought by briefing; • Importance of briefing to patient safety;

Table 30: Physical and Human resources involved in each perioperative process' activity.

Process	Activity	Activity Classification	Human Resources	Physical Resources
Preoperative	External Surgical Consultation	Operation	• Patient; • Surgeon;	• Consultation office;
	Surgical Decision	-	• Surgeon; • Patient;	• Consultation office;
	No surgery	Operation	• Patient;	-
	Surgical proposal	Operation	• Surgeon;	• Information system;
	Wait to perform exams	Queue	• Patient;	-
	Wait for blood analysis; Wait for electrocardiogram; Wait for thorax tele radiography;	Queue	• Patient;	-
	Complementary Diagnosis Exams – blood analysis; electrocardiogram; thorax tele radiography.	Operation	• Therapeutics and diagnosis' Technicians; • Patient;	• Exam's room;
	Identify the missing exams	Operation	• Doctor; • Patient;	-
	Wait for exams' results and consultation	Queue	• Patient;	-

Process	Activity	Activity Classification	Human Resources	Physical Resources
	Provide information about the surgical procedure	Operation	• Patient; • Surgeon; • Anesthesiologist;	• Consultation office;
	Wait for Anesthesia Consultation	Queue	• Patient;	-
	Anesthesia Consultation	Operation	• Patient; • Anesthesiologist;	• Consultation office;
	Wait to perform exams	Queue	• Patient;	-
	Complementary Diagnosis Exams	Operation	• Patient; • Therapeutics and diagnosis' technicians;	• Exam's room;
	Wait for internment	Queue	• Patient;	
	Internment	Operation	• Patient; • Medical team's doctor; • Nurse;	• Internment ward – nursery; • Bed;
	Wait for anesthesiologist visit	Queue	• Patient;	-
	Confirmation of patient's data	Operation	• Anesthesiologist; • Patient;	• Internment ward – nursery; • Bed;
	Wait to perform the missing exams	Queue	• Patient;	-
	Perform the required exams	Operation	• Patient; • Therapeutics and diagnosis' technicians;	• Exam's room;
	Surgery Cancelled	Operation	• Patient; • Doctor;	-
	Wait for the exams and exam's results	Queue	• Patient;	-
	Exam's evaluation	Operation	• Anesthesiologist; • Surgeon; • Patient;	• Internment ward – nursery; • Bed;

Process	Activity	Activity Classification	Human Resources	Physical Resources
	Assist the patient to achieve requirements for surgery;	Operation	• Doctor; • Patient;	-
	Wait for transport to interchange area	Queue	• Patient;	• Bed;
	Request blood unit	Operation	• Anesthesiologist; • Technician;	-
	Wait for delivery of blood unit in OT	Operation	• Nurse; • Operational assistant;	• OR;
	Patient transference to interchange area	Transport	• Operational assistant; • Patient;	• Internment's ward bed;
Intraoperative	Patient's arrival to OT	Operation	• Operational assistant; • Patient;	• Internment's ward bed; • OT's interchange area;
	Patient's received by anesthesiologist	Operation	• Operational assistant; • Anesthesiologist; • Patient; • Anesthetics Nurse;	• OT's interchange area; • Internment's ward bed;
	Anesthesiologist receives the case	Operation	• Anesthesiologist; • Service doctor;	• OT's interchange area;
	Wait for patient's preparation to enter OR	Operation	• Patient;	• Internment's ward bed; • OT's interchange area;
	Patient's preparation to enter the OR	Operation	• Patient; • Anesthetic Nurse; • Operational assistant; • Anesthesiologist;	• OT's interchange area; • Internment's ward bed; • surgical marquise;

Process	Activity	Activity Classification	Human Resources	Physical Resources
	Patient's transport to OR	Transport	• Operational assistant; • Patient;	• surgical marquise;
	Wait to prepare patient for anesthesia	Queue	• Patient;	• surgical marquise; • OR;
	Patient preparation to anesthesia	Operation	• Patient; • Operational assistant; • Anesthesiologist; • Anesthesia nurse; • Circulant nurse;	• surgical marquise; • OR;
	OR material's preparation	Operation	• Circulating nurse; • Instrument nurse;	• OR; • Surgical instruments; • Surgical equipment;
	Anesthesia induction	Operation	• Patient; • Anesthesiologist; • Anesthetic Nurse;	• Preparation room; • Surgical marquise; • OR; • Anesthetic instruments; • Anesthetic equipment;
	Wait anesthesia effects	Queue	• Patient; • Anesthesia nurse; • Operational assistant; • Anesthesiologist;	• OR; • Surgical marquise; • Positioning equipment;
	Position the patient for surgery	Operation	• Patient; • Responsible surgeon; • Anesthesiologist; • Anesthetic nurse;	• OR; • surgical marquise; • Positioning equipment;
	Surgeon's preparation	Operation	• Surgeon;	• Disinfection material;

Process	Activity	Activity Classification	Human Resources	Physical Resources
				• OR's disinfection room;
	Wait for conditions to start surgery	Queue	• Surgeons; • Circulating nurse; • Patient; • Anesthesiologist; • Anesthesia nurse; • Instrument nurse; • Auxiliary assistant;	• OR; • Surgical marquise; • OR equipment; • OR instruments; • Positioning equipment;
	Surgery	Operation	• Patient; • Responsible Surgeon; • Surgeon Assistants; • Anesthesiologist; • Instrument Nurse; • Anesthetic Nurse; • Circulant Nurse; • Operational Assistant;	• OR; • Surgical marquise; • OR equipment; • OR instruments; • Positioning equipment;
	Request bed and transport	Operation	• Anesthesia nurse/ circulating nurse;	• Bip;
	Used material confirmation	Inspection	• Circulating nurse; • Instrument nurse;	• OR; • Compresses; • *Cirurgia Segura software;*
	Clean sterile field and patient	Operation	• Instrument nurse;	• OR; • Surgical marquise; • OR equipment; • OR material;
	Administer patient's medication and wake him/her up	Operation	• Anesthesiologist; • Anesthetic's nurse; • Patient;	• OR; • Surgical marquise; • Medication;

Process	Activity	Activity Classification	Human Resources	Physical Resources
	Wait for patient to wake and be responsive	Queue	• Anesthesiologist; • Patient; • Anesthesia nurse; • Circulating nurse; • Operational assistant;	• OR; • Surgical marquise; • Anesthesia equipment;
	Cleaning and disinfection the OR	Operation	• Operational assistant;	• OR; • Cleaning and disinfection equipment;
	Patient's transference to interchange area	Transport	• Operational assistant; • Anesthesiologist; • Anesthetic nurse; • Patient;	• OR; • Interchange area; • Surgical marquise;
	Prepare the patient to leave the OT	Operation	• Operational assistant; • Anesthesia nurse; • Anesthesiologist; • Circulating nurse; • Patient;	• Interchange area; • Surgical marquise; • Post operatory ward's bed;
	Wait for conditions to transport	Queue	• Anesthesiologist; • Patient; • Anesthesia nurse;	• Interchange area; • Post operatory ward's bed; • Medicines;
	Patient's transference to post operatory unit	Transport	• Anesthesiologist; • Anesthetic nurse; • Operational assistant;	• Post operatory ward's bed; • Patient's documentation; • Medicines;
Postoperative	Arrival at PACU	Operation	• Anesthesiologist; • PACU's doctor; • Anesthesia nurse; • PACU's nurse; • Operational assistant; • Patient;	• Post operatory ward's bed; • Patient's documentation; • Medicines;

Process	Activity	Activity Classification	Human Resources	Physical Resources
	Wait for PACU's team to be available	Queue	• Anesthesiologist; • Anesthesia nurse; • Patient;	• Post operatory ward's bed; • Patient's documentation; • Medicines;
	Briefing between the medical team	Operation	• Anesthesiologist; • PACU's doctor; • Anesthetic nurse; • PACU's nurse;	• Monitor and control equipment; • Patient's documentation; •
	Patient's control and monitoring	Operation	• PACU's doctor; • PACU's nurse; • Patient;	• Monitor and control equipment; • Post operatory ward's bed;
	Wait for conditions to PACU's discharge	Queue	• Patient; • PACU's doctor; • PACU's nurse;	• Monitor and control equipment; • Post operatory ward's bed;
	Access patient's conditions to discharge	Inspection	• PACU's doctor; • Patient;	• Monitor and control equipment; • Post operatory ward's bed;
	Wait for bed and transport	Queue	• Patient;	• Monitor and control equipment; • Post operatory ward's bed;
	Patient's transport to UCI	Transport	• Patient; • UCI's/ PACU's Doctor;	• Monitor and control equipment;

Process	Activity	Activity Classification	Human Resources	Physical Resources
			• UCI's/PACU's Nurse;	• Post operatory ward's bed;
	Arrival at Intermediary Care Unit	Operation	• Patient; • IntCU/ PACU's Doctor; • IntCU's/PACU's Nurse;	• Monitor and control equipment; • Post operatory ward's bed;
	Arrival at UCI	Operation	• Patient; • IntCU/ PACU's Doctor; • IntCU's/PACU's Nurse;	• Monitor and control equipment; • Post operatory ward's bed;
	Patient's transport to IntCU	Transport	• Patient; • UCI's/ PACU's Doctor; • UCI's/PACU's Nurse;	• Monitor and control equipment; • Post operatory ward's bed;
	Wait for bed and transport	Queue	• Unit's doctor; • Unit's nurse; • Patient;	• Monitor and control equipment; • Post operatory ward's bed;
	Patient's transport to UCI	Transport	• Patient; • IntCU's doctor; • IntCU's nurse;	• Post operatory ward's bed; • Monitor and control equipment;
	Discharge from unit	Operation	• Patient; • Unit's doctor;	• Post operatory ward's bed; • Monitor and control equipment;
	Waiting for bed and transport	Queue	• Patient;	• Post operatory ward's bed;
	Patient's transport to Nursery	Transportation	• Patient; • Operational assistant;	• Nursery's bed;
	Arrival at nursery	Operation	• Patient; • Operational assistant;	• Nursery's bed;

Process	Activity	Activity Classification	Human Resources	Physical Resources
			• Nurses;	
	Patient's accompaniment	Operation	• Patient; • Nurse;	• Nursery's bed; • Medicines;
	Wait for discharge	Queue	• Patient;	• Nursery's bed; • Medicines;
	Patient's Discharge	Operation	• Patient; • Surgeon	• Consultation office;

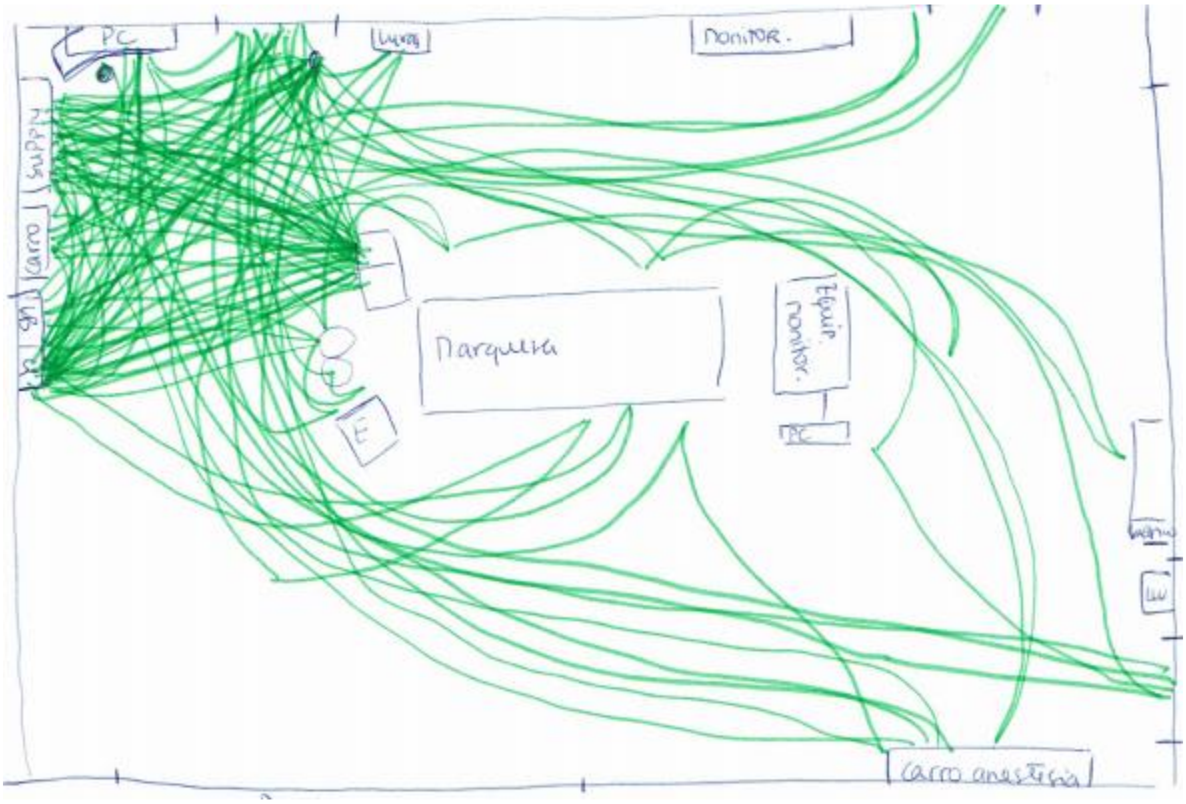

Figure 26: Spaghetti Diagram of the Circulant Nurse's circuit, in OT3 (Vascular Surgery).

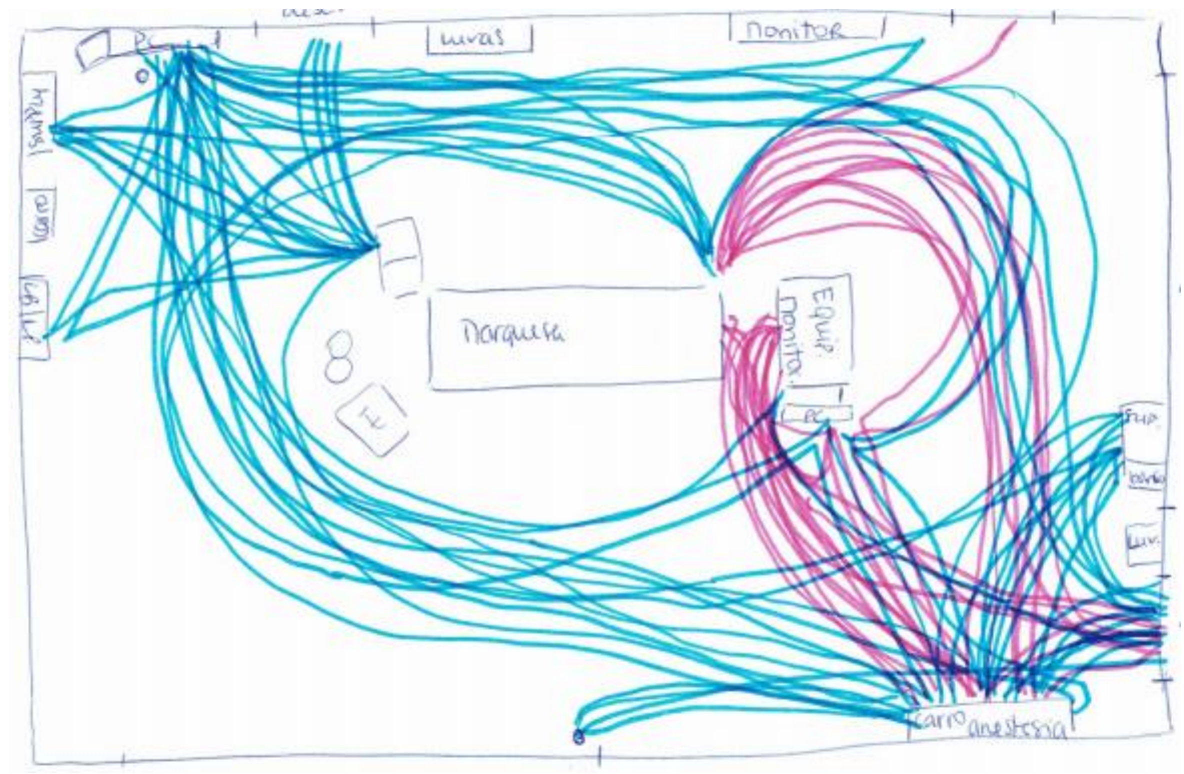

Figure 27: Spaghetti Diagram of Anesthesiologist (purple) and Anesthetist Nurse's (blue) circuit, in OT3 (Vascular Surgery).

Figure 28: Spaghetti Diagram of the Circulant Nurse's circuit, in OT4 (General Surgery).

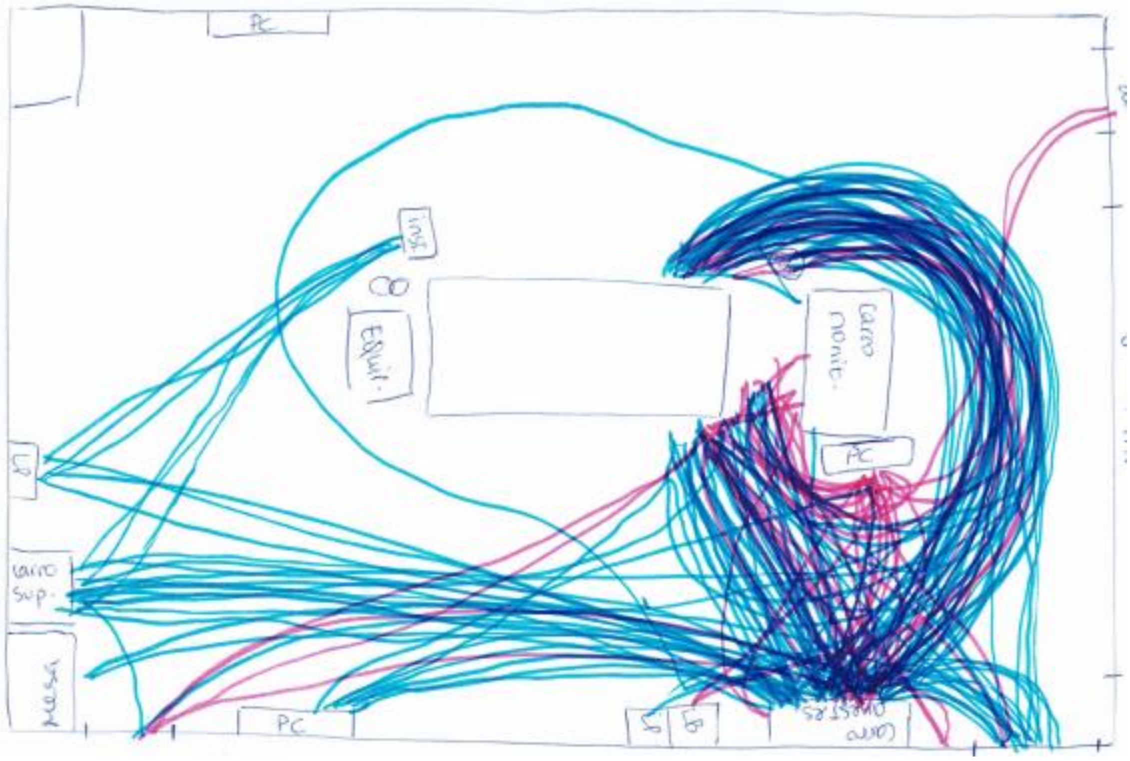

Figure 29: Spaghetti Diagram of Anesthesiologist (purple) and Anesthetist Nurse's (blue) circuit, in OT4 (General Surgery).

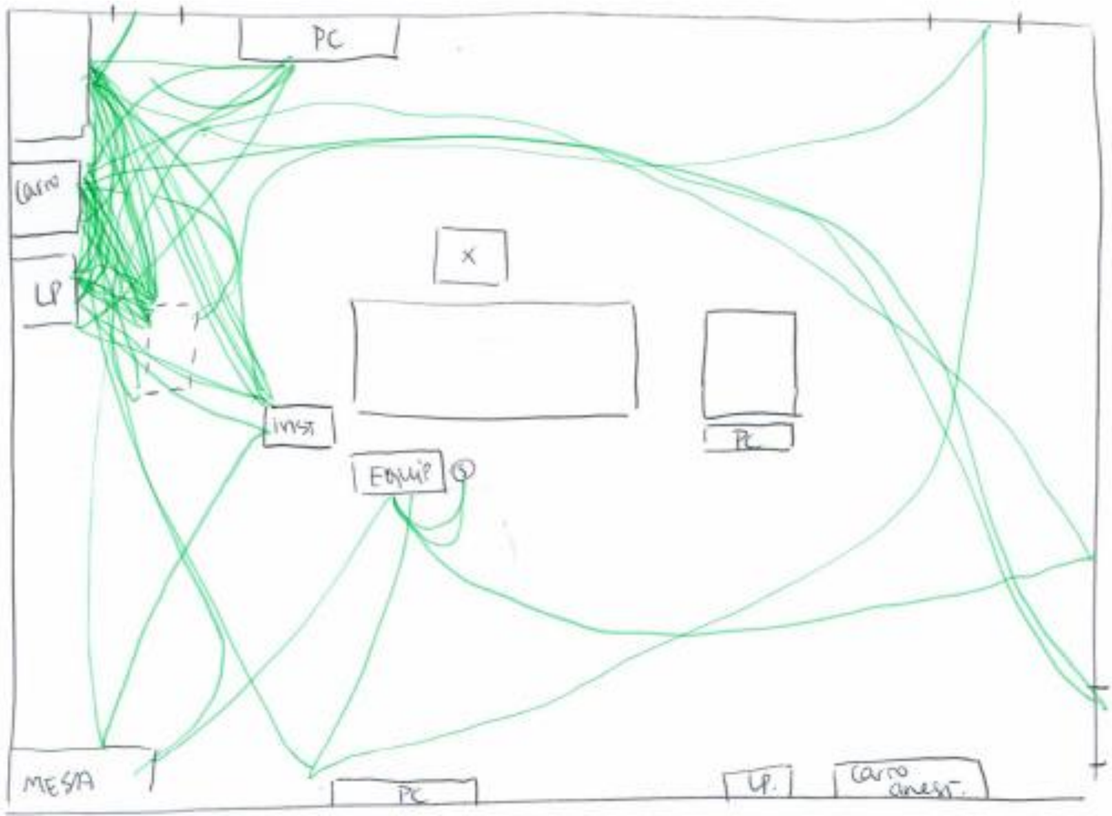

Figure 30: Spaghetti Diagram of the Circulant Nurse's circuit, in OT4 (Urology).

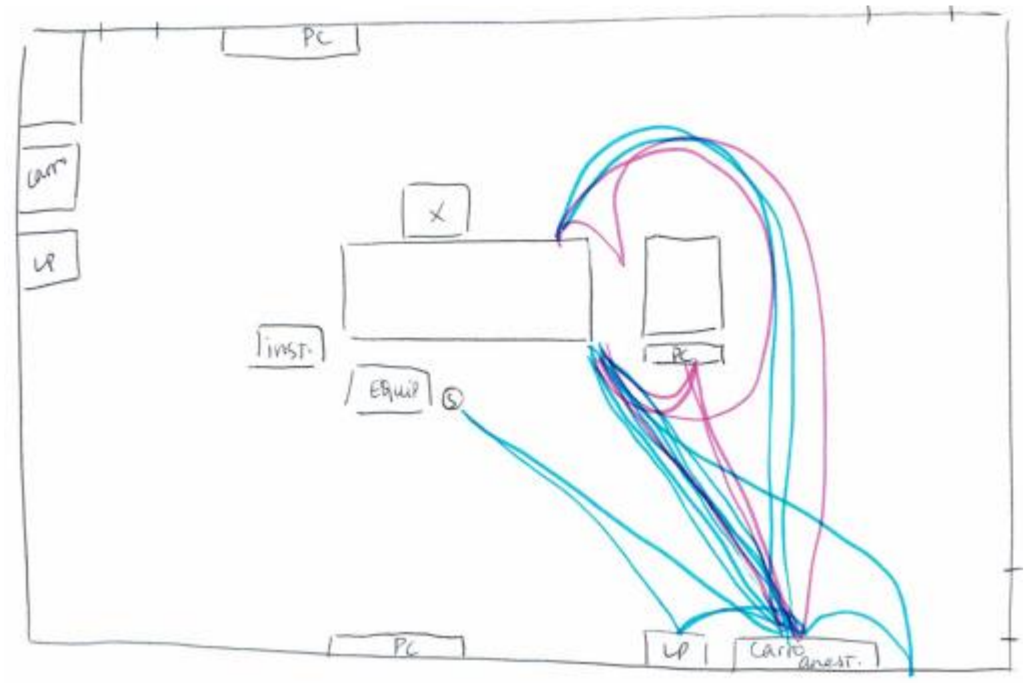

Figure 31: Spaghetti Diagram of Anesthesiologist (purple) and Anesthetist Nurse's (blue) circuit, in OT4 (Urology).

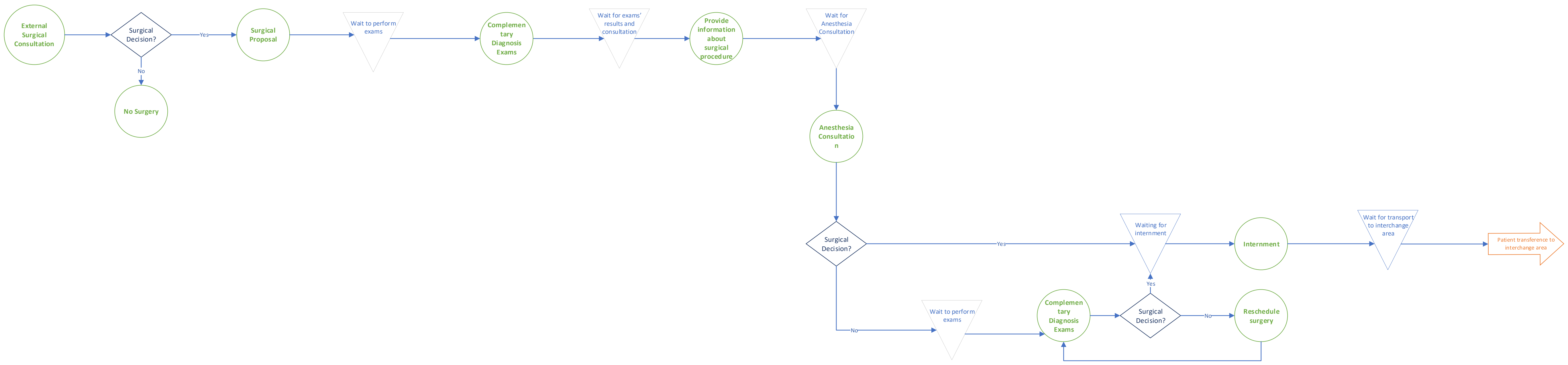

Figure 32: Process map of Preoperative Process - macro scale.

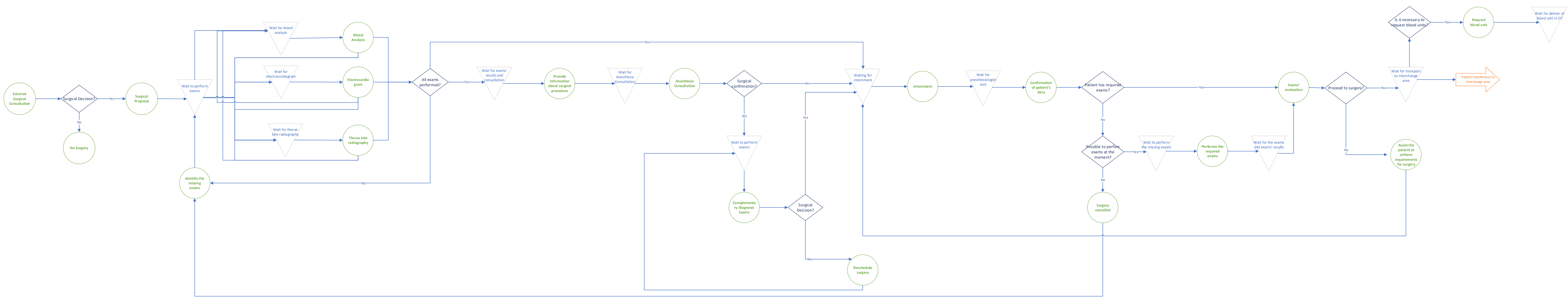

Figure 33: Process map of Preoperative Process - micro scale.

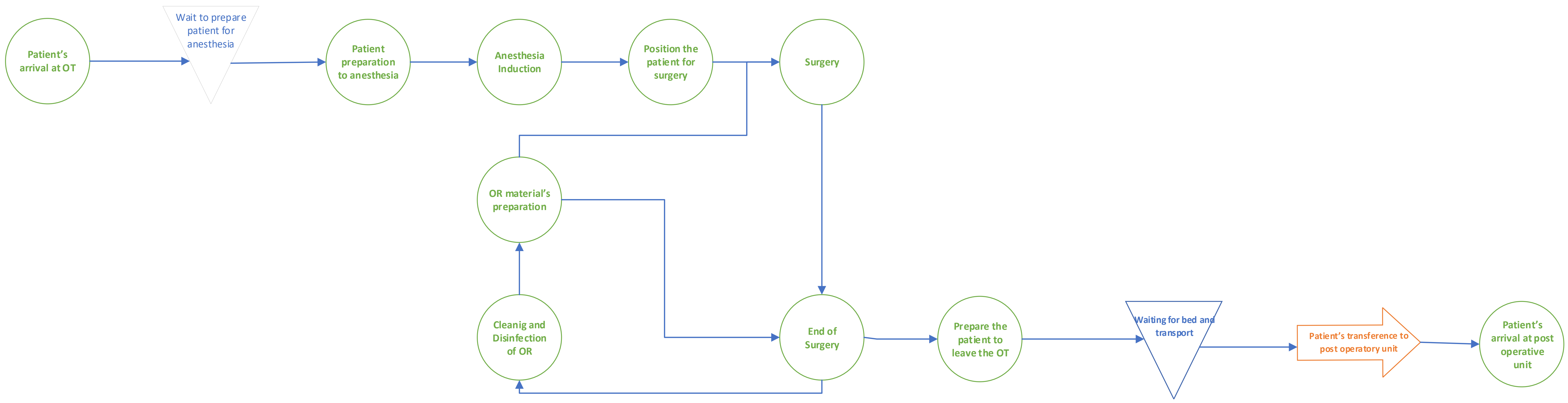

Figure 34: Process map of Intraoperative Process - macro scale.

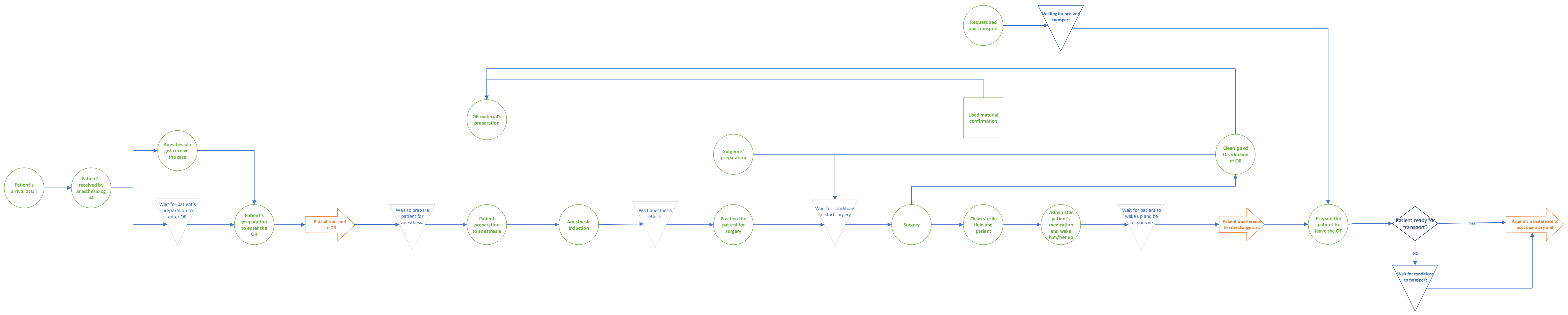

Figure 35: Process map of Intraoperative Process - micro scale.

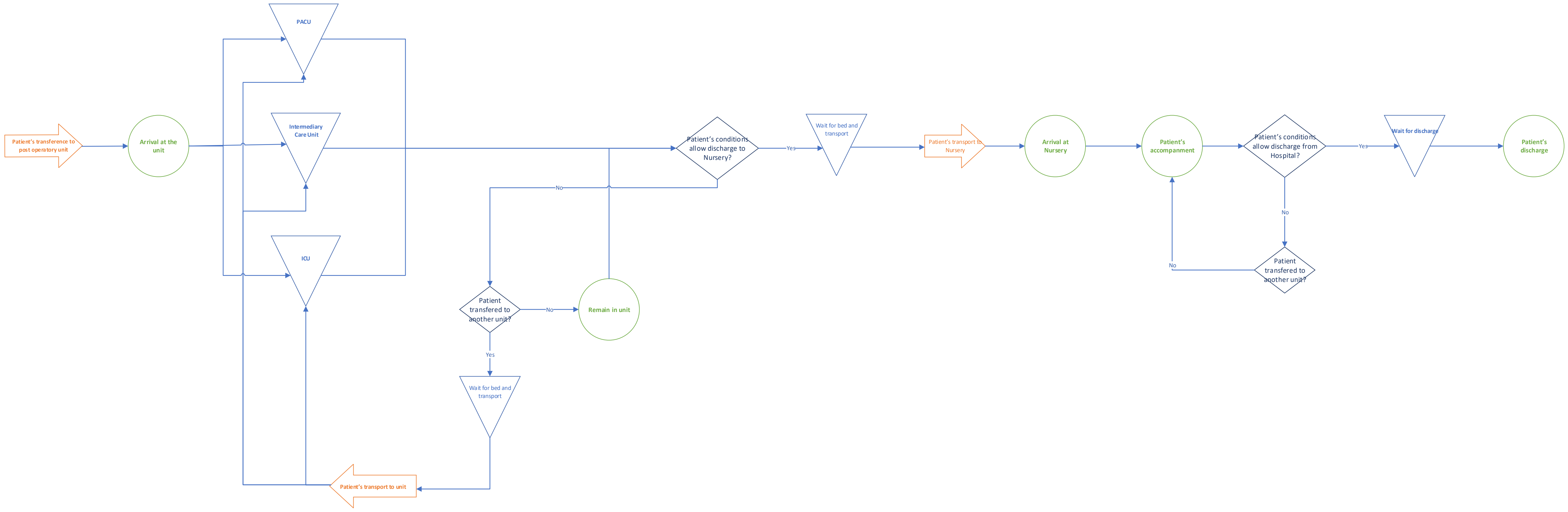

Figure 36: Process map of Postoperative Process - macro scale.

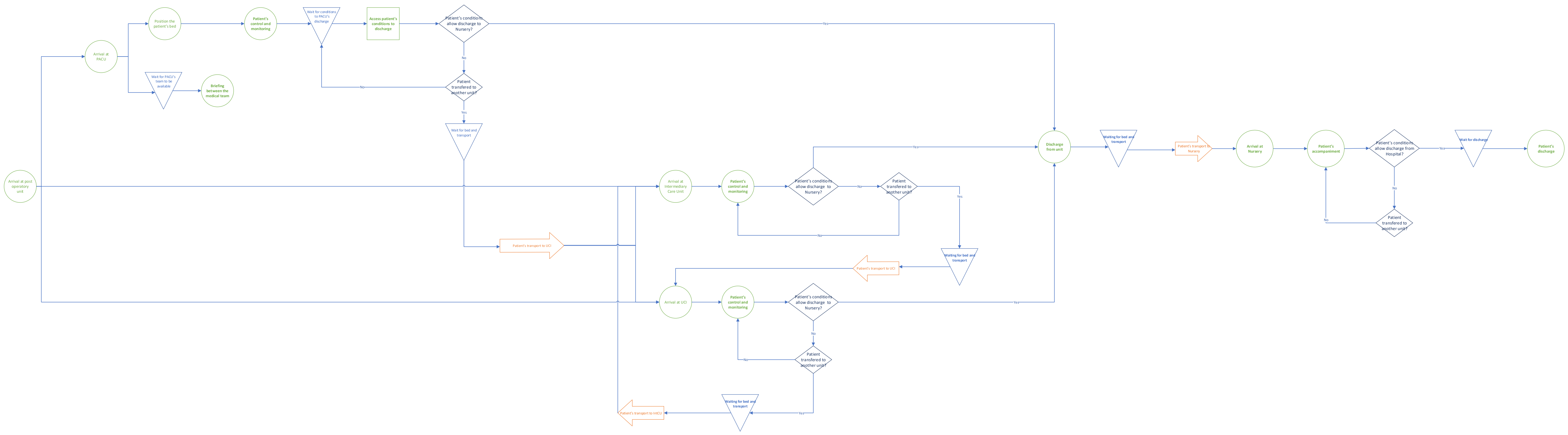

Figure 37: Process map of Postoperative Process - micro scale.