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NEUROCRITICAL CARE IN INTENSIVE CARE UNITS

INTERNSHIP REPORT

HEALTHCARE ENGINEERING

Available online on: https://travaux.master.utc.fr/formations-master/ingenierie-de-la-sante/ids071/

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ABSTRACT

Human Factors or Ergonomics is the study of how humans behave physically and psychologically in relation to environments, products, or services.

Interface Design is an evolving discipline. Ecological Design Interface combines concepts of Humans and environment, and the concept of Display.

Cognitive Work Analysis (CWA) is a formative, constraint-based framework for analyzing complex sociotechnical systems such as Intensive Care Units. The CWA framework helps to develop support tools such as an Abstraction Hierarchy (AH).

This internship report focuses on how CWA can be applied to neurocritical care in the intensive care unit using EID.

RESUME

Les facteurs humains ou l'ergonomie est l'étude de la façon dont les humains se comportent physiquement et psychologiquement par rapport aux environnements, aux produits ou aux services.

La conception d'interfaces est une discipline en évolution. L'interface de conception écologique (EID) combine des concepts d'humains et d'environnement, et le concept d'affichage.

L'analyse cognitive du travail (CWA) est un cadre formatif basé sur des contraintes pour analyser des systèmes sociotechniques complexes tels que les unités de soins intensifs. Le cadre CWA aide à développer des outils de support tels que, par exemple, une hiérarchie de l'abstraction (AH).

Dans ce rapport de stage, nous verrons ici comment la CWA est appliquée aux soins neurocritiques dans l'unité de soins intensifs à travers la conception d'une interface suivant l'EID.

KEYWORDS

WDA - EID - Neurocritical Care - ICU - neuro-ICU

ABBREVIATIONS

AH: Abstraction Hierarchy

AIDL: Advanced Interface Design Lab

CBB: Centre for Bioengineering and Biotechnology

CPP: Cerebral Perfusion Pressure

CSF: Cerebrospinal fluid

CWA: Cognitive Work Analysis

ConTask: Control Task (Analysis)

EEG: Electro Encephalo Gram

EID: Ecological Interface Design

GCS: Glasgow Coma Scale

HF: Human Factors

HFES: Human Factors and Ergonomics Society

ICU: Intensive Care Unit

ICP: Intra Cranial Pressure

IH: Intracranial hypertension

MAP: Mean Arterial Pressure

SARS: Severe Acute Respiratory Syndrome

SHAP: SHapley Additive exPlanations

SYDE: SYstem Design Engineering

UW: University of Waterloo

UXD: User Experience Design

WDA: Work Domain Analysis

WFH: Work From Home

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Introduction

The world has known the biggest pandemic in 2020 due to Covid-19. According to the World Health Organization, a pandemic is defined as "an epidemic occurring worldwide, or over a very wide area, crossing international boundaries and usually affecting a large number of people"[1] [2]. By epidemic, we mean "a widespread occurrence of an infectious disease in a community at a particular time"[3].

Covid-19 is a new disease which has similar symptoms to common cold such as fever, dry cough, and tiredness. It spreads through close contact with an infected person. This coronavirus disease is caused by a virus called SARS-CoV-2. Coronaviruses are part of a large family of viruses that can cause illness in animals or humans. The spread of this new infectious disease began in Wuhan, China, in December 2019 and has reached today 216 countries, causing 495 760 confirmed deaths and more than 9 843 073 confirmed cases on June 27th 2020 [4]–[6].

Anyone can catch this disease without or with mild symptoms in most cases. However, Covid-19 can also evolve into severe respiratory illnesses, like pneumonia, with an occurrence of 1 infected person out of 5 [4]. Two categories of people are most likely to be affected by these severe symptoms, the elderly, and those with underlying conditions such as high blood pressure, heart and lung problems, diabetes or cancer. These persons need a hospital treatment and patient care in the ICU [7].

This has shown the importance of having functional and efficient ICU units in order to improve the quality of care given by physicians and nurses. Thus, it would be interesting to think about how the Ecological Design Interface (EID) and Cognitive Work Analysis (CWA) methods, could improve the quality of care.

I. Internship environment

1. THE UNIVERSITY OF WATERLOO

University of Waterloo, with its leading "spirit of the why not", is a public research university created in 1957 by business leaders to address industry needs. Its particularity is that the inventor ownership of intellectual property, so it is an incentive way to attract leading and entrepreneurial researchers. It's the largest post-secondary program in the world with the co-op Education.

- UW has reached the first rank of Comprehensive Research for 12 years consecutive years according the research info source 2019 [8], [9].
- It is also the most innovative university in Canada for 28 years [9], [10].
- And the first in the world for student-employer connections [9], [11].

University of Waterloo is composed by different schools such as Public Health and Health Systems, Accounting and Finance, Architecture, Planning, Computer Science, Optometry and Vision Science, Pharmacy, but also by different faculties: Applied Health Sciences, Arts, Engineering, Environment, Mathematics and Science.

2. THE FACULTY OF ENGINEERING

It's Canada's Largest Engineering School with more than 8000 undergraduate students, 13% international students and about 2000 graduate students.

The Faculty of Engineering is composed by 8 following departments:

- Electrical and computer engineering
- Mechanical and mechatronics engineering
- Systems Design Engineering
- Management Sciences
- Chemical engineering
- Civil and Environmental engineering
- School of architecture including integrated design
- Conrad School of Entrepreneurship and Business

They offer ,among the mentioned departments, 15 bachelor degree programs and 37 graduate degree programs.

Here you can find the Waterloo Engineering Integration Complex in the campus in Figure 2. That aims to be intelligent, connected, digital and physical. The E7 Integration Hub is in Figure 1.

Figure 1 - Waterloo Engineering - E7 Building - Source: Author

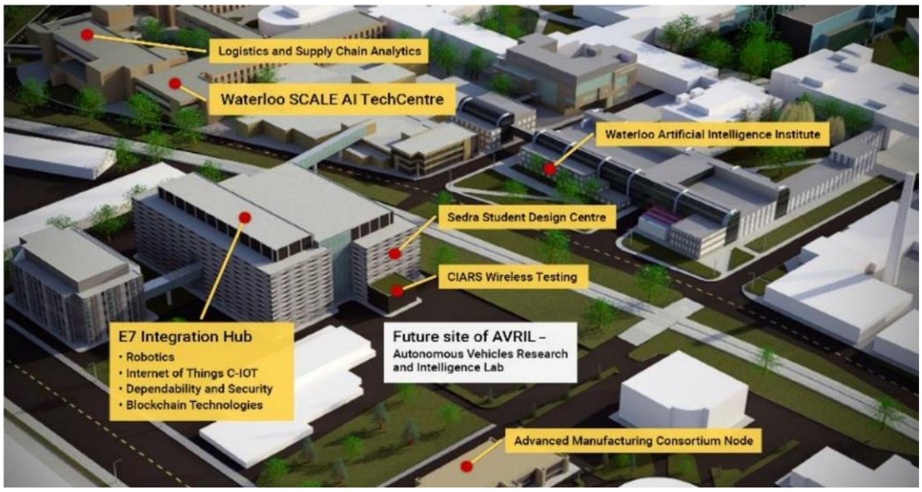


Figure 2 - Waterloo Engineering Integration Complex - Source: UW

3. THE SYSTEM DESIGN ENGINEERING DEPARTMENT

The department of SYDE was established 40 years ago and until today it is still providing the most flexible programs and various areas of research such as environmental socioeconomic and political aspect. Started at 1969, the department was considered unique due to the interdisciplinary programs with leading and developing topics. The distinctive nature of the offered programs within the department emerged from the topics covered in the curriculum. Topics covered include political, environmental, economic, social and technical aspects of engineering.

4. THE CENTRE FOR BIOENGINEERING AND BIOTECHNOLOGY

In 2011, the UW established the centre CBB. Catherine Burns, my internship supervisor, was the founding Executive Director (ED) until May 2020. Since its establishment, CBB focused on facilitating tactical multidisciplinary research that connects technology to biosciences, health sciences and environmental sciences. Moreover, CBB strived to cover industrial challenges by holding events with companies, discussions and academic seminars and workshops. Financially, CBB uses independent funding system to supports researchers by applying to grants and seeking alternative funding opportunities.

Location

The Centre is located at 200 University Ave West, Waterloo, ON N2L 3G1 | East Campus 4 Building, Room 2001, in Figure 3.

Figure 3 - East Campus 4 Building - Source: Author

The Staff and Leadership Organization

Since May 2020, **Karim S. Karim** became the new Executive Director of the CBB [12]. The CBB team is also composed by:

- **Carly Turnbull**, the project co-ordinator, interim manager, program Development and Partnerships
- **Charlotte Armstrong**, the administrative assistant
- **Colin Russell**, Manager, Program Development and Partnerships
- **Catherine Burns**, the founder and former CBB Executive Director

The product is knowledge transfer and partnerships.

Budget

The Centre's budget is not part of the public domain, but financial statements about the University of Waterloo can be found here.

5. THE ADVANCED INTERFACE DESIGN LAB

At UW, each faculty and department relate to laboratories. The AIDL is attached to SYDE. Catherine Burns, my supervisor, is the director of this lab.

The AIDL, focus on collaborative processes between technology and human users with the goal of developing advanced interfaces in the following domains:

- Defence and Aviation
- Financial Trading
- Healthcare
- Automated Vehicles
- Human Interaction with Artificial Intelligence
- Other Projects in Interface Design, Collaboration, and Visualization

6. MY ROLE IN THIS INTERNSHIP: RESEARCH ASSISTANT

During my internship, I was assigned the position of research assistant. I worked on an ICU neurocritical care project with a PhD student, Ece Uereten. Aside from my main project, I participated in a secondary project covering Artificial Intelligence in Finance. I covered visualisation of SHAP[1] for a peer to peer landing website managed by Murat Dikmen.

In both projects, work was done in groups which sharpened my teamwork skills. Team meetings were done every week to provide updates about the projects progress and to show the professional development acquired by team members. During each meeting, members would present challenges they faced and skills they learned while working on the assigned projects. Moreover, the meetings were used to discuss future steps and tasks for each member.

My role as a research assistant was affected by Covid-19 thus restricting my responsibilities to mainly conducting literature reviews, requesting supplies necessary for the project, attending online project meetings, attending an international conference HFES symposium, and summarizing project results through presentations.

[1] The SHAP is a method used to explain individual predictions based on the game theoretically optimal shapley values. It was introduced by Lundberg and Lee in 2016.

II. Neurocritical care in ICU

Neurocritical care is a medical area that deals with the treatment of serious diseases in the nervous system and identifies, prevents and treats them. Neuro-ICU is the place where the patients are admitted and taken care of.

1. INTENSIVE CARE UNITS IN CANADA

The intensive critical care unit provides intensive care to severely ill patients. According to a report, in 2013–2014, **11% of the more than 2 million adult hospital stays in Canada** are spent in an ICU (outside Quebec) [13].

The average daily cost of an ICU stay is estimated to be **as high as 3 times the average cost of a day's stay** in a general ward. This is because ICU stays are more resource intensive in terms of personnel to equipment and medication. For these reasons, it is important to better understand the use of this constrained resource with respect to operating patterns, patient flow, trends in admissions, patient populations and process of care for those treated in ICUs [13].

There are three different types of ICUs:

- The general ICUs
- The specialized ICUs: for example, ***neuro-ICU***
- The paediatric ICUs

Nonetheless, it could also be a combination of the any of the above types.

In ICUs, a lot of medical devices are connected to the patients. There is a lot of data obtained from patients through monitors, ventilators, EEG etc. Nurses perform their care oversight using a **flowsheet** as presented in Figure 5. They note down data related to cardiovascular, respiratory, neurologic, nursing care, nursing assessment, clinical notes and fluid balance. Although this flowsheet is thorough it presents limitation such as the multitude of variable parameters that need to be taken into account. Another limitation is the lack of continuous tracking of a patient's vitals. As a result, physicians do not get the complete picture of the patient's history. The patient's life can be at stake for a few minutes or even seconds for patients in neurocritical care. **The main issue is to track data continuously and show data on one screen.** It will aid physicians in storing those data.

Name ____________ MRN ____________ Date ____________

NURSING ASSESSMENT

NA = Not applicable **SN** = See Notes **EPR** = See EPR

Critical-Care Pain Observation Tool **Instructions:** The patient must be observed at rest to obtain the baseline value of CPOT, during the nociceptive procedures, and before and at the peak effect of the analgesic agent. Document the highest score observed during the observation period.

Time →																																		
NRS Pain Scale																																		
CPOT Pain Scale																																		

Standardize Safety Check	0001	0730	1530	1930
• Positive patient indentification (I.E. check ID band, allergy band, fall risk, etc.).				
• Insuring alarms are on and functional (I.E. bed, chair, equipment, etc.)				
• The status of emergency equipment (I.E. functioning, O_2 sensor, suction, etc.).				

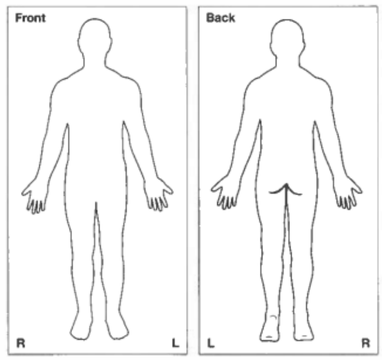
Respiratory	0001	0730	1530	1930
Cough Present Y = Yes N = No				
Gag Present Y = Yes N = No				
Chest Expansion S = Symmetrical AS = Asymmetrical				
Respirations – Rhythm Pattern R = Regular IR = Irregular ND = No distress L = Laboured T = Tachypenic SOB = Shortness of breath				
Breath Sounds / Lobe Location CL = Clear INS = Inspiratory EXP = Expiratory W = Wheezes C = Crackles D = Diminished RUL = Right upper lobe RML = Right middle lobe LUL = Left upper lobe RLL = Right lower lobe LLL = Left lower lobe BB = Bilateral bases AL = All lobes				
Chest Tube Location #1 ______cm suction #2 ______cm suction F = Float visible P = System patent G = Gravity AL = Air leak	#1			
Chest Drainage S = Serous SS = Serosanguineous SA = Sanguineous P = Purulent PCD = Percutaneous chest drain location **Chest Tube Dressing** in EPR	#2			

Cardiovascular	0001	0730	1530	1930
Capillary Refill B = Brisk D = Absent S = Sluggish				
Pulses present (✔) DP/PT – Right				
DP/PT – Left				

Gastro Intestional	0001	0730	1530	1930
Abdomen S = Soft D = Distended F = Firm P = Pulsatile B = Bruising T = Tender				
Bowel Sounds P = Present A = Absent H = Hyperactive F = Flatulence D = Diminished/Hypoactive				
Stool C = Continent IC = Incontinent RT = Rectal tube CO = Colostomy I = Ileostomy OT = Other Last BM ____				
Tubes Type OG = Orogastric NG = Nasogastric GT = G-Tube PP = Post Pyloric NGT Placement ☐				
Drain/Suction H = High L = Low Cont = Continuous I = Intermittent C = Clamped G = Gravity				
Feeds **Extra Water Flush** - Sign on paper MAR				
Initials				

Genitourinary	0001	0730	1530	1930
Urine Pattern V = Voided HNV = Has not voided C = Continent IC = Incontinent T = Toileting Q2H F = Foley CBI = Cont bladder irrigatn PD = Peritoneal dialysis HD = Hemodialysis I/O = In & out catheter See bladder scan Policy # 20.30.002				
Urine Appearance C = Clear CL = Cloudy D = Dilute CN = Concentrated S = Sediment H = Hematuria				

Integument	0001	0730	1530	1930



Initials				

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Figure 4 – Extract of the flowsheet used by nurses and physicians in ICU at hospital X - Source: Hospital X

As it is shown in Figure 6, the ICU is a **complex dynamic sociotechnical environment**. Numerous interactions between patients and caregivers take place, as well as interactions of the patients with support staff such as pharmacists and technicians. Caregivers are changing. Similarly, the patient’s conditions change as well. For example, a nurse takes care of the patient and take notes in the flowsheet. Then, the physician threats the disease of the patient in critical conditions. Afterwards, the patient is connected to several medical devices. All these interactions should be taken in account in our EID.

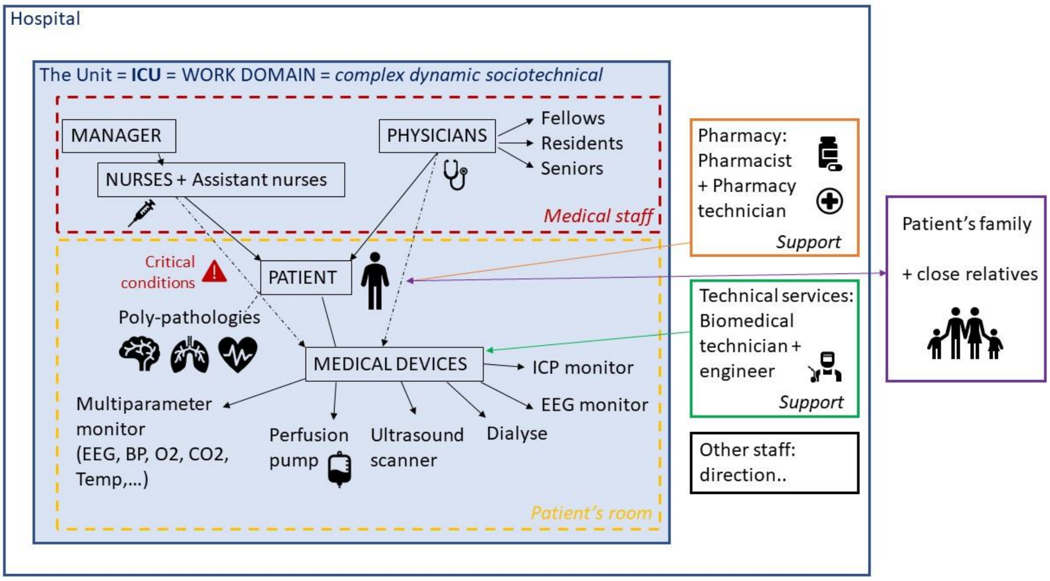

Figure 5 - An understanding of ICU environment as a complex dynamic sociotechnical - Source: Author

Thus, we are investigating whether **integrating the information from a range of medical devices into an integrated display in neuro-ICU using EID** would be efficient. This integrated display could be dynamic or static. This EID should facilitate decision-making for healthcare personnel.

2. EID AND CWA MODELLING

Ecological Design Interface

The word ecological deals with the relationship between humans and the environment. Interface design relates to the display. EID is known for **visualizing functional relationships in a "quick glance" with little cognitive efforts**. The motivation for EID originated from problems arising in the interface design of complex sociotechnical systems. It could be applicated to neurocritical care in ICU.

Why choose EID instead of UXD? UXD is user-centered windows-based interface whereas EID takes a wider account of the environment. It bridges between humans and the program/environment. An understanding of human conception, cognition, and behavior is critical to designing interfaces. That much can be learned by getting feedback from actual users of the interface, at the early design stages, and then through testing a various point in the design [14].

EID approach is used: when asking users is not possible, when we want users to become experts and when we want to handle the unexpected [14].

In complex systems, it is useful to understand how the system works, before beginning the design [14]. There are two key concepts in EID from cognitive engineering research: the Abstraction Hierarchy (AH) and the Skills, Rules, Knowledge (SRK) framework. That is why the CWA approach was our first step.

Cognitive Work Analysis

As previously mentioned, ICU is a complex dynamic sociotechnical system therefore, to understand how ICU works and its constraints, we used CWA modelling. It allowed us to understand physicians but also to focus on the workload.

The word cognitive is associated with human factors or ergonomics. The word work is related to a world not a task. Analysis refers to a modelling tool. It is used to understand the world in a formative way [15]. Technology may change. Users may change. Tasks may change. Information system should overcome the fluctuation.

This modelling could be applied to the neuro-ICU. It requires **5 steps** as shown in Figure 7.

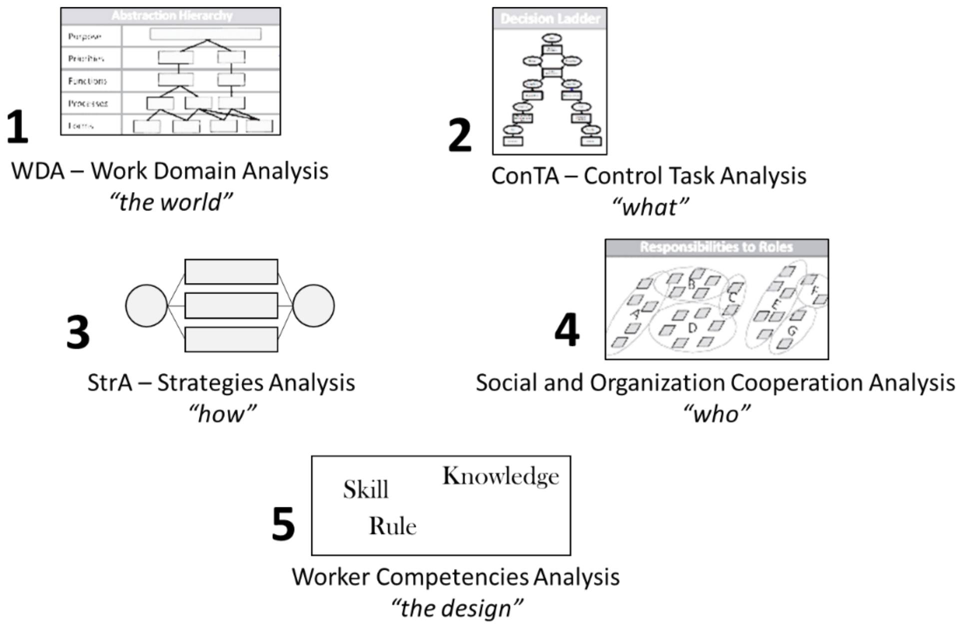

Figure 6 - Different steps of CWA - Source: AIDL

The CWA framework includes five different phases: the **work domain analysis (WDA)** through the ***Abstraction Hierarchy (AH)***, the **Control task (or activity) analysis** which leads us to the ***decision ladder***, the **strategies analysis**, the **social organisation and co-operation analysis**, and the **worker competencies analysis**.

CWA will enable us to **understand how the ICUs environment works and the different flows and parameters to take in account for the interface design**. We will focus on the first point. The AH is the key tool in performing WDA and thus EID[14].

Work Domain Analysis (WDA) & Abstraction Hierarchy (AH)

As a first level of the CWA, WDA requires a description of domain through the AH as a first step of the designing project. In other words, we are **defining the system of interest**. This description is context independent. The analyses, and resultant diagrams, are not specific to any technology; rather they represent the entire domain[15], [16].

The AH is a "treelike structure with multiple levels and each level are different from others and are ordered along a dimension"[14]. Each level has a means-ends link that can be answered by "how" and "why".

There are **5 steps**, represented in Figure 8: the **functional purpose**, the **abstract function**, the **generalised function**, the **physical function** and the **physical forms**. For each step, a question is to be answered.

Level 1: Purpose	What was the work domain designed to do? What problem do we want to solve?
Level 2: Abstract Function	What are the underlying laws or principles?
Level 3: Generalised Function	What are the processes that are involved?
Level 4: Physical function	What equipment is involved and what is its capability?
Level 5: Physical form	What is the physical appearance and loctaion of that equipement?

Figure 7 - The five levels of the AH and associated questions - Source: EID Book

My collaborator, Ece, as a first step of the EID and through her observation at Hospital X, carried out a previous work on the AH, in Figure 9. It focuses on the neuro-system and cognition as shown in Figure 9.

Level of Abstraction	Nervous System & Cognition	Neurocritical Care Monitoring & Treatment
Purpose	Interpretation of sensory input Effects responses Monitoring internal environment Coordination of body movement Homeostasis Mental activity	Improve patient condition Enable independent living (quality of life) Long-term stability
Balances	Control of O_2, temperature, heart rate, release of hormones Regulation of organ system Control of thoughts, movement, emotions, desires	Balance of patient goals (quality of life, advance directives) Balance of treatment goals (comfort, healing, length of stay)
Processes	Contraction of skeletal muscles Involuntary control of muscles Neurological functions Conscious perception Control smooth muscle & glandular tissue in digestive system Reflex Information transfer between brain & body Respiration Healing process Use of energy	Medications – process of influence Physical interventions (ventilation, draining) – process of influence Monitoring
Physiology	*Body* Patient *Systems* Autonomous nervous system (ANS) Central system (CNS) Somatic nervous system (SNS) *Organs* Brain Spinal Cord Heart Lungs	Medication Ventilator Drains Medical staff Sensors, Monitors
Physical Form	Patient type (adult, pediatric) Patient condition (obese, elderly, frail etc.) Connection of CNS to (sensory) organs, muscles, blood vessels, glands Condition (ICP, HR, BP, lung stiffness) Medication (type, dose, form of administration, side effects) Disease (type, state)	Monitoring sensors & equipment (location, capability) Drains (location) Ventilator (settings & type of ventilation) Side effects Damage (type, amount, location)

Figure 8 - AH: Neurocritical care in ICU - Source: Ece Uereten

I contributed to this latter AH by focusing more on the **quality of care and staff issues**. As shown in Figure 10, an answer to the first question, what problem do we want to solve in ICU, would be to improve patient care, patient conditions and maintain patient safety. For each level, the AH is providing an answer to the question of each level of the AH.

The quality of care is defined as the **perceived quality**, the **efficiency** and the **efficacy of care**. The perceived quality is, here, the level of quality of the care service as perceived by the patient in a more or less subjective way. By efficacy, we mean the ability of reaching a goal of treatment by the physician, for example, whereas efficiency refers to the ability to reach this goal of treatment with the minimum waste of resources.

	PATIENT CARE	STAFF ISSUES	Questions
Functional purpose Level 1	Improve **patient care** + Improve **patient conditions and maintain patient safety**		What problem do we want to solve?
Abstract Function Level 2	**Quality of care** = Perceived quality + efficiency of care + efficacy of care		What are the underlying that are involved?
Generalized Function Level 3	**Perceptions/Sensations** ; Check-up/**Observations** ; **Medication**/Metabolism ; **Physical Intervention** - **Monitoring**	**Processes of providing critical care**	What are the processes that are involved?
Physical Function Level 4	**Patient** – **Medical devices** : multiparameter monitor – ***blood test*** – **drugs**/drip – ventilator – dialyse	**medical staff** (nurse, physicians, respiratory therapist) – **social workers** - **support staff** (pharmacist, technician, engineer, cleaner…)	What equipment is involved and what its capability?
Physical Form Level 5	**Patients conditions** (type of disease ex: diabetes, age, type); **Pain or damage** (appearance, type, amount, location) **Monitoring equipment + screen interface** (location, capability, type of signal, color of signal) Monitoring sensors (side-effects, color, type) **Sample tube** (number, type) **Drains** (location + number), **patient circuit or pipe** (type), **ventilator** (settings, alarms, type, side-effects) **Medication** (type, form, color, dose, side-effects) Dialysate circuit, filtrate circuit, **dialysis monitor,** dialyzer	**Capability, knowledges, competences** (Diploma, number of years working, type of profession) **Fatigue, Burn-out, healthcare**(number of hour of work per day, workload, overtime, mental and physical health = healthcare personnel) Percentage of **Fulfillment** at work (motivations,..)	What is the physical appearance and location of that equipment?

Figure 9 - AH: Neurocritical care in ICU - Source: Author

By their capability, knowledges or competences, the quality of care can be affected by the caregivers, and also by the fatigue, burn out or fulfillment at work.

Later, we merged both our AH into one describing widely the environment in Figure 11.

	NERVOUS SYSTEM & COGNITION	PATIENT CARE, MONITORING & TREATMENT	STAFF ISSUES
Functional purpose Level 1	Interpretation of sensory input – Effects responses – Monitoring internal environment – Coordination of body movement – Homeostasis – Mental activity	Improve **patient care** + Improve **patient conditions and maintain patient safety (enable independent living + long term stability)**	
Abstract Function Level 2	Control of O2, temperature, heart rate, release of hormones – Regulation of organ system – Control of thoughts, movement, emotions, desires	**Quality of care** = Perceived quality + efficiency of care + efficacy of care **Balance of patient goals + Balance of treatment goals**	
Generalized Function Level 3	Contraction of skeletal muscles – involuntary control of muscles – Control smooth muscle & glandular tissue in digestive system – Reflex – Respiration – Neurological functions – Healing process – Conscious perception – Information transfer between brain & body – Use of energy	**Perceptions/Sensations** ; Check-up/**Observations** ; **Medication**/Metabolism (process of influence) ; **Physical Intervention** (process of influence) **; Monitoring**	**Processes of providing critical care**
Physical Function Level 4	**Body: patient** – **Systems**: Autonomous nervous system (ANS), Central System (CNS), Somatic nervous system (SNS) – **Organs**: Brain, Spinal cord, Heart, Lungs	**Patient** – **Medical devices** : multiparameter monitor, ventilator, dialyse – ***blood test*** – **drugs**/drip	**Medical staff** (nurse, physicians, respiratory therapist, medical assistant, pharmacist)
Physical Form Level 5	**Patients conditions** (obese, elderly, frail, age, type); **Pain or damage** (appearance, type, amount, location) **Disease** : type, state **Connection of CNS** to (sensory) organs, muscles, blood vessels, glands **Physical Condition** ICP HR BP lung stiffness **Monitoring equipment + screen interface** (location, capability, type of signal, color of signal); Monitoring sensors (side-effects, color, type) **Drains** (location + number), **patient circuit or pipe** (type), **ventilator** (settings, alarms, type, side-effects) Dialysate circuit, filtrate circuit, **dialysis monitor**, dialyzer? **Sample tube** (number, type) **Medication** (type, form, color, dose, side-effects)		**Capability, knowledges, competences** (Diploma, number of years working, type of profession) **Fatigue, Burn-out, healthcare**(number of hour of work per day, workload, overtime, mental and physical health = healthcare personnel) Percentage of **Fulfillment** at work (motivations,...)

Figure 10 - merged AH: Neurocritical care in ICU - Source: Ece Uereten & Author

List of parameters

With the help of the AHs (Figure 10 and Figure 9), my collaborator, the brainstorming tool and the flowsheets for each level, we have listed all of the parameters and variables that could arise in Figure 12.

	Variables AH1	Variables AH2
Level 1	Time of treatment Length of stay Number of readmission	Time of treatment Length of stay Number of readmission
Level 2	Percentage of patient recovery Mortality rate Length of stay	Pain scale Comfort?
Level 3	Maximal concentration (Tmax), Area under the concentration–time curve (AUC, 0–10 h) Half-life (t1/2) Elimination rate constant (Ke) Total body clearance (CL) Time of ventilation Amount of ventilation support	Percentage of success treatment? Time of ventilation Amount of ventilation support Amount of monitoring system Amount of monitor interface
Level 4	Type and amount of blood test Amount of medical staff Amount of support staff Frequency of dialysis and duration Amount of affected organs + severity rate Amount of ventilators changes Amount of medication and type	Amount of medical staff Amount of medication Medication type Amount of ventilators changes
Level 5	Temperature GCS : Scale pain, Eye response, Verbal response, Motor response, Pupil size, Speed for the pupillary reactivity, Limb movement (binary) Chemistry : Glu, Na, K, Cl, Bicarbonate, Urea, Creatinine, Ca, Mg, P, AST, ALD, ALP, LD, Bilirubin, Albumin, Protein, Amylase, Troponin, Lactate, CK, Hematology : Hb, Leucocytes, Platelest, Hematocrit, Neutrophils, Lymphocytes, Pro Time, INR, aPTT Nursing Assessment? Nursing Care? Neurological : Coma Scale, Pupil Scale, Limb Movment; ICP Monitoring : EVD : MAP, ICP, CPP, CSF Drained CC, Level; EEG (ICP: Waveform, Pressure; EEG : Amplitude, Frequency, Spatial distribution Waveform (monophasic, biphasic or polyphasic) BP : Pressure (Systolic, diastolic, mean arterial), waveform EEG: Frequencies, SpO2/EtCO2 : Rate R/IR Number year of experience Type of diploma + Variables AH2	Pharmacology: Maximal concentration (Tmax), Area under the concentration–time curve (AUC) Half-life (t1/2), Elimination rate constant (Ke), Total body clearance (CL) Respiratory : Initials RN/RT, Mode, PS/PC Level, Rate Setting and Patient, Vt Setting and Patient, VE Total, Peak Flow, Waveform, PAW (Peak and Mean), Peep/CPAP, I:E Ratio/ I time, FIO2/NO, SaO2/ETCO2, pH, PCO2, PO2, TCO2, SO2, ABG's time, DB+C/Incentive, Secretions, Suction-Oral, EET/Trach, PZA (Art, PA, CVP), Time of respiratory Cardiac : Heart Rate, Wafeform, DBP, SBP, Mean BP Hemodynamics : PAP, RAP/CVP, LAP/PCWP, SVR/PVR, MAP Drips/Drugs : mL/h (speed), time Temperature Drains: location and amount Damage : type, location, amount Disease : type and state Medication: type, dose, side-effects, form of administration Patient type : adult, pediatric Patient condition : Age of patient Identity of Patient (name, patient number) Patient history NRS Pain Scale, CPOT Pain Scale Clinical notes? Radiology

Figure 11 - List of the parameters for each level of the AHs – source: Author

This list of parameters has been detailed in Appendix 1. For each parameter, we provided a definition, its units and range.

Focus on neuro-parameters

Three neurologic variables are important in neurocritical care and used in neuro-ICU: GCS, ICP and EEG.

Glasgow Coma Scale (GCS)

This is a **neurological scale** which aims to provide a reliable and objective way of recording the level of consciousness of a patient. The score lies between 3 to 15. Three elements are considered: Eyes response (5 grades), Verbal response (5 grades) and Motor response (6 grades).

Intra-Cranial Pressure (ICP)

This is an **invasive parameter**. It represents the pressure applied by fluids such as CSF inside the skull and on the brain tissue. The CPP is the difference between the MAP and the ICP. Normal ICP lies between 5 to 10 mmHg [17]. IH, IICP or raised ICP is the most common clinical condition that requires treatment to reduce ICP.

Electroencephalogram (EEG)

This is a **non-invasive parameter**. It is the recording or measurement of cerebral bioelectric activity using electrodes placed on the scalp. It aims to monitor sedation or diagnosis of seizure activity. There exist 3 types of examinations: standard (short term), Holter (long term) and encephalic death. EEG is characterised by: Amplitude, Frequency, Spatial distribution and Waveform (monophasic, biphasic or polyphasic). There are 4 categories of frequencies: delta (<3.5Hz), theta (4 to 7.5 Hz), alpha (8 to 13 Hz) and beta (>13 Hz).

For each of these parameters, we tried to find out which companies sell these types of monitor and the available design screen types.

A first draft of the EID on Figma

After the results were obtained in this list of parameters and also from the observations my collaborator made during her time in the hospital, a first draft of the design was established on Figma, as shown in Figure 13.

Figma is a **free collaborative interface design tool**. Thanks to the UW, a free education version was available enabling us to work in team.

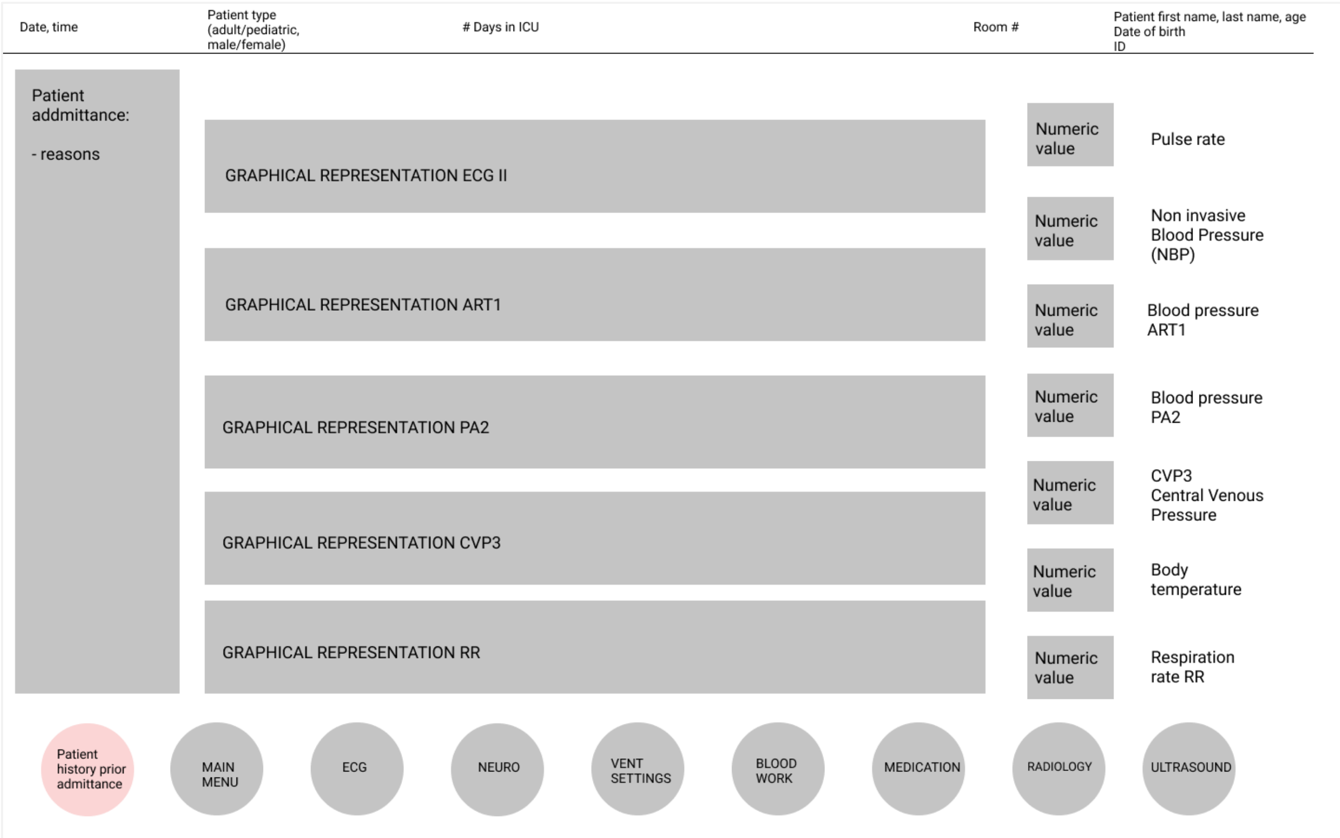

Figure 12 - EID front page - vital sign parameters - Source: Ece Uereten & Author

In order to take into account all persons likely to use this interface, a **gray scale** will be used. This is done specifically because there may be people with **color blindness** within the nursing staff.

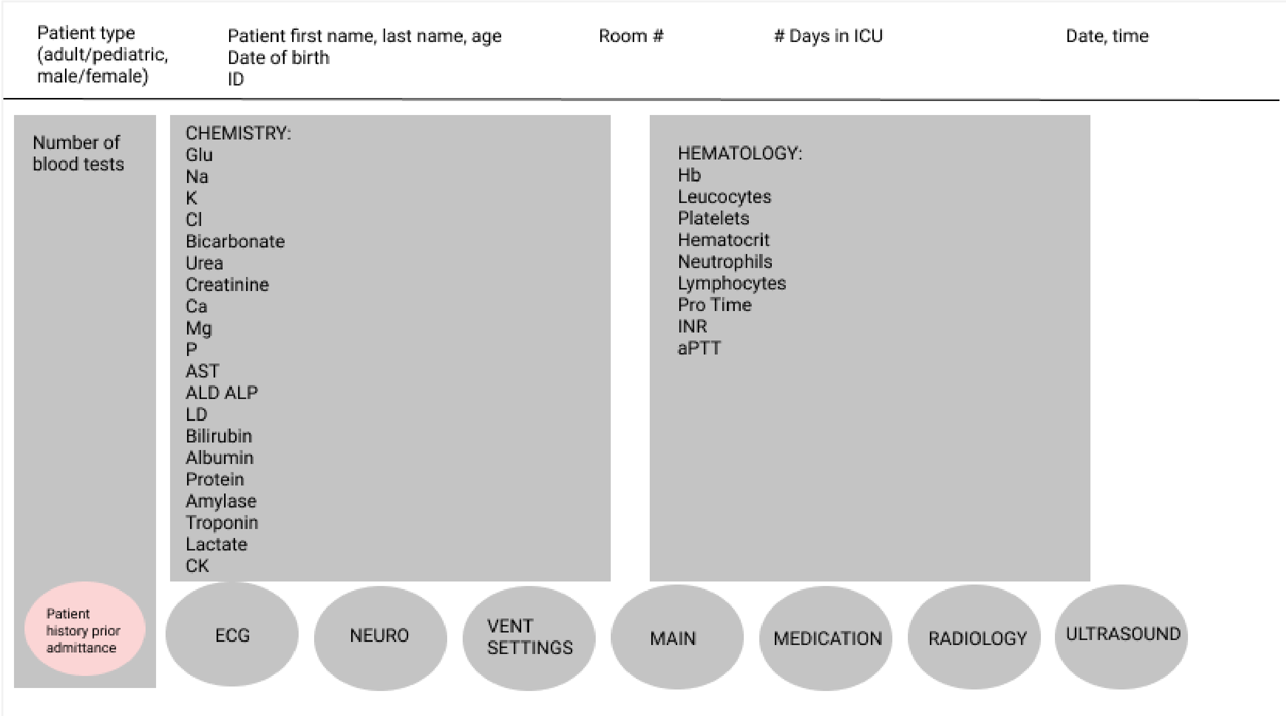

Figure 13 – EID front page - blood work – Source: Ece Uereten & Author

In Figure 14, the blood work parameters are presented as an example. In all screen, some important parameters are shown such as time, date, identification of the patient.

Feedback from the users: Personas and Scenarios

The next step was to **understand the use cases**. For that, we needed to understand clinicians better. Since we could not interview nurses and physicians due to the circumstances, we had to find another way to **create scenarios and personas**. We created personas to **understand clinicians' perspectives and tasks/challenges**. We researched on typical ICU scenarios to prepare for a comparison and talked to a physician working at hospital X about them.

Personas

The goal here is to **create reliable and realistic representations of our key audience segments for reference**. The personas would be the clinicians that we are considering in our AH. We had to understand their perspectives and many examples were found online. Thanks to an opensource website, we got some personas which are listed in the Annexe II: Primary Care Physician, Hospital Nurse, Medical Assistant, Hospital Pharmacist, and an example in Figure 15.

Sharon Benton, MD – Primary Care Physician

42 years old; Married, two kids; Typically works 60 hours/week.

Narrative

Sharon is a primary care physician who works in a small satellite practice that is part of a large integrated delivery system. She gets a lot of personal satisfaction from having long-term relationships with her patients, who appreciate the personalized care she provides. She spent 11 years in higher education and remains in debt to this day.

Sharon often feels that when practicing medicine, she is working for the technology instead of the other way around. She is often frustrated by how many complex documents need to be created to maximize billing, despite the fact that the same information must be displayed in a way that is relevant and clear when used to work up a patient. Sharon comfortably uses consumer technology in all aspects of her life.

Figure 14 - Example of personas - Source: EHRA

Personas represent a major user group for our EID. It expresses and focuses on the major needs and expectations of the caregivers (nurses and physicians) and give a clear picture of their expectations and how they're likely to use the site. It describes real people with backgrounds, goals, and values.

Clinical scenarios

The goal was to look at specific diseases and the parameters the clinicians need to check. It is a **brief description of a clinical situation or event**. The purpose of the Clinical Scenarios is to provide background and illustrate the need for the development of technical solutions [18].

A complete scenario would look like the whole process of a patient coming into the ICU with x problem. This would be something we give to our participants, so they can set all necessary parameters on the interface to treat the patient.

We created a **list of scenarios**. For each system, we have different cases with outcomes variables, process variables and variables. The different mentioned systems are neurologic, pulmonary, cardiovascular, renal-fluid-electrolytes, gastro-intestinal-metabolic-nutrition and hematologic/infectious disease.

After discussion with the physician, we obtained a list of the most critical case scenarios encountered in neuro-ICU. These are **subarachnoid hemorrhage**, **intracerebral hemorrhage**, **acute ischemic stroke**, **traumatic brain injury**, **spinal cord injury** and **status epilepticus**. We also obtained more relevant scenarios cases through simulation training databases. These scenarios cases would help to improve our EID.

3. USABILITY STUDY

To have a better understanding of the boundaries of the existent software, a **usability study** will be done at hospital X in the fall or winter term.

Hospital X is currently using the software A of Company A as a bedside monitor. We found another new software B commercialised by Company B. This software only collects, visualizes, and stores ICU data in near real-time. It does not make any diagnosis. Software B can track data from software A through servers and uses the HL7[2] standard to communicate.

With my collaborator, we compared both **technical parameters and functional parameters** as well as the **design differences** in both displays. My collaborator has attended to a demo of the new software B. Some of the limits of these two software are **data storage, data tracking, visualisation and alarms**.

For example, we found out at that a real display size is typically between about 15" and 19". At this moment, we adjusted the size of our EID draft.

The aim of this usability study is to compare the current ICU software A to the new software B. The findings of this study and the limits will help us in our EID in neurocritical care.

[2] HL7 is an international standard that is used to transfer data between software applications. It is used by different healthcare providers.

III. Personal feedback and career professional assessment of this internship

1. PERSONAL FEEDBACK

This was my first experience in a non-European country. It was very exciting and interesting to discover the North American culture, and especially Canadian one. It allowed me to improve my communication skills in English. This internship also gave me the opportunity to attend an **international symposium on Human Factors and Ergonomics in Health** care from May 18th to 21th 2020, which was done virtually due to the pandemic circumstances. It is worthy of mentioning that I also participated in the Fluxible online event, which was a Canadian UX Festival, on June 4th.

Moreover, I discovered the field of research, which I was apprehensive of previously. In particular, I was introduced to the field of design, in which I had no experience and knowledge of prior to this internship.

Autonomy, freedom of planning, pleasure of investigating in the health care field were the keys words that I retained from this experience. Teamwork allowed me to work in complementarity with my colleagues, each with a different and complementary backgrounds.

In addition, we had to adapt ourselves with the changing sanitary requirements and **Work from Home** (WFH). Even though we could not interview the health personnel because they were needed most in the ICU, my research work was not affected. International solidarity linked to the pandemic made it easier for us to occasionally to get free valuable online information about companies and medical devices. Working from home required us to have a balance between our personal and private life but also to have an efficient schedule allowing consistency.

Many thanks are due to our supervisor, Mrs. Burns, who organized weekly meetings and fostered effective communication with the members of the laboratory with the tools available. Furthermore, the UTC set up a support unit for isolated students during lock-down.

Despite the quarantine, the first two months allowed me to meet and keep in touch with many students from UW. It also made me aware of how lucky I was to live in France and to have access to the university for free. We do not burden of study loan which something I am grateful for. I am also grateful for the Eramus+ program otherwise I wouldn't have been able to embark on this journey.

2. CAREER OBJECTIVES

Since my bachelor's degree, I have had three different experiences in different settings: hospital, company/association and laboratory, which gives me a more complete vision of the types of trades in health engineering. This research internship opened me to the idea of finding a job in this field. Two aspects of biomedical engineering I missed were the contact with other people, especially the medical staff, and contact with medical devices. The job of application engineer combines both. Also, it requires a lot of travel and I love to travel. Monitoring and cardiovascular are the areas in which I am particularly interested.

Conclusion

In neurocritical care, patients in ICU are in critical and sensitive states. As we have seen in Europe and also in America, the overload of ICUs during the pandemic was unexpected. In these cases, it is important for caregivers to make the best decisions during treatment as quickly as possible.

Through CWA modeling, our AH was able to lead us to a first draft of our EID. The second step of this project will be to **apply the scenarios** on the EID considering the second step of the CWA modeling: **The Control Task Analysis,** which is complementary to the EID. This aims to take into account the decision ladder of the medical staff to help the physician with the diagnosis. A small mistake can jeopardize patient safety. The sooner we can diagnose the pathology, the better the treatment plan would be meaning enabling a better quality of care.

Bibliographic references

[1] Heath Kelly, 'The classical definition of a pandemic is not elusive', *WHO*, doi: 10.2471/BLT.11.088815.

[2] Jamie Ducharme, 'World Health Organization Declares COVID-19 a "Pandemic." Here's What That Means', *Time*, Mar. 11, 2020.

[3] Oxford Dictionary, 'Definition of Epidemic', *https://www.lexico.com/*. Accessed: Jun. 28, 2020. [Online]. Available: https://www.lexico.com/en/definition/epidemic.

[4] World Health Organization, 'Technical guidance: Naming the coronavirus disease (COVID-19) and the virus that causes it'. Accessed: Jun. 28, 2020. [Online]. Available: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/technical-guidance/naming-the-coronavirus-disease-(covid-2019)-and-the-virus-that-causes-it.

[5] World Health Organization, 'Coronavirus disease (COVID-19) pandemic', *https://www.who.int/*. https://www.who.int/emergencies/diseases/novel-coronavirus-2019 (accessed Jun. 28, 2020).

[6] World Health Organization, 'Q&A on coronaviruses (COVID-19)', *https://www.who.int/*, Apr. 17, 2020. https://www.who.int/news-room/q-a-detail/q-a-coronaviruses (accessed Jun. 28, 2020).

[7] Celiac Disease Foundation, 'Celiac Disease and COVID-19', *Celiac Disease Foundation*. https://celiac.org/celiac-disease-and-covid-19/ (accessed Jun. 28, 2020).

[8] Research Infosource Inc., 'Canada's Top 50 Research Universities 2019', 2019. https://researchinfosource.com/top-50-research-universities/2019/top-research-universities-by-tier-corp (accessed Jun. 28, 2020).

[9] 'UW, University of Waterloo', *University of Waterloo*, Nov. 03, 2016. https://uwaterloo.ca/content/home (accessed Jun. 28, 2020).

[10] Macleans.ca, 'Canada's best universities by reputation: Rankings 2020', *https://www.macleans.ca/*, Oct. 03, 2019. https://www.macleans.ca/education/canadas-top-school-by-reputation-2020/ (accessed Jun. 28, 2020).

[11] 'QS Graduate Employability Rankings 2019', *Top Universities*, Feb. 01, 2017. https://www.topuniversities.com/university-rankings/employability-rankings/2019 (accessed Jun. 28, 2020).

[12] 'Centre for Bioengineering and Biotechnology, CBB Team', *Centre for Bioengineering and Biotechnology*, Jun. 18, 2015. https://uwaterloo.ca/bioengineering-biotechnology/about/people/cbb-team (accessed Jun. 28, 2020).

[13] CIHI, Canadian Institute for Health Information, 'Care in Canadian ICUs', Aug. 2016. Accessed: Jun. 28, 2020. [Online]. Available: https://secure.cihi.ca/free_products/ICU_Report_EN.pdf.

[14] Catherine M. Burns and John R. Hajdukiewicz, *Ecological Interface Design*. CRC Press, 2004.

[15] K. J. Vicente, *Cognitive Work Analysis: Toward Safe, Productive, and Healthy Computer-Based Work*. CRC Press, 1999.

[16] J. Rasmussen, 'The role of hierarchical knowledge representation in decisionmaking and system management', *IEEE Trans. Syst. Man Cybern.*, vol. SMC-15, no. 2, pp. 234–243, Mar. 1985, doi: 10.1109/TSMC.1985.6313353.

[17] C. A. Mount and J. M Das, 'Cerebral Perfusion Pressure', in *StatPearls*, Treasure Island (FL): StatPearls Publishing, 2020.

[18] ASTM International, 'Annex B of ASTM Standard F2761-09: Clinical Context and Clinical Scenarios'. 2013, Accessed: Jun. 28, 2020. [Online]. Available: http://www.mdpnp.org/uploads/Clinical_Scenario_and_CConOps_definitions_and_framework.pdf.

Appendices

Annexe I - List of parameters

List of Parameters	Definition	Units	Range
Time of treatment	The time between the first and the last treatment order.	Seconds, Minutes, Hours, Days, Months, Years	Not determinable (depends on the patient) [0:∞[
Length of stay	The time between patient arrival and discharge of the ICU.	(Seconds), Minutes, Hours, Days, Months, Years	Not determinable (depends on the patient) [0:∞[
Readmissions	The number of times being admitted to an ICU again.	0, 1, 2, 3, … (positive integer)	Not determinable (depends on the patient) [0:∞[
Patient recovery	Which criteria include the patient recovery?	%	[0:100]
Mortality rate	The relation between alive and dead patients in the number of deaths in ICU.	%	[0:100]
Comfort in the ICU	To be defined with criteria: • Type/size of room • Type of bed • Hospital meal • Single or shared room	%	[0:100]
Severity rate	The amount of affected organs by disease.	%	[0:100]
Pain scale			
NRS: Numeric Rating Scale		0: No pain 10: Worst pain possible	[0:10]
CPOT: Critical Care Pain Observation Tool		3: No pain 12: Maximum Pain	[3:12]
GCS: Glasgow Coma Scale	Neuro	3: No pain 15: Maximum Pain	[3:15]
Respiratory parameters			
Time of ventilation	The time between starting and stopping the mechanical ventilation on the patient.	Seconds, Minutes, Hours	[0:∞[

Ventilation support	The amount of how much the patient is supported by mechanical ventilation.	% 0: the patient breathes by him-/herself 100: ventilator supplements respiratory function	[0:100]
Ventilator changes	The amount of how many times the patient circuit is changed to a different setting.	0, 1, 2, 3, … (positive integer)	Not determinable (depends on the patient) [0:∞[
Respiratory rate (f)	The number of breaths per minute or, more formally, the number of movements indicative of inspiration and expiration per unit time.	b/m	10-20
Tidal volume (Vt)	The volume of air moved into and out of the lungs during each ventilation cycle.	Ml/kg	5-15
Oxygen concentration (FiO2)	The percentage or concentration of oxygen that a person inhales.	%	b/w 21-90
I:E ratio	The ratio of inspiratory time: expiratory time.	X	1:2
Flow rate or peak inspiratory flow rate	The maximum flow at which a set tidal volume breath is delivered by the ventilator.	L/min	40-100
Sensitivity/trigger	Determines how much effort the patient has to exert before his inspiration is augmented by the ventilator.	cmH2O	0.5-1.5
Pressure Limit		cmH2O	10-25
PEEP	Abbreviation for positive end-expiratory pressure. A method of ventilation in which airway pressure is maintained above atmospheric pressure at the end of exhalation by means of a mechanical impedance, usually a valve, within the circuit.	cmH2O	5-10

Other parameters	VC NIF Cuff pressure Extubated VENT ETT/Trach size Taped Air Entry Adventitious Sounds Initials RN/RT, Mode, PS/PC Level, Rate Setting and Patient, Vt Setting and Patient, VE Total, Peak Flow, Waveform, PAW (Peak and Mean), CPAP, I time, FIO2/NO, SaO2/ETCO2, pH, PCO2, PO2, TCO2, SO2, ABG's time, DB+C/Incentive, Secretions, Suction-Oral, EET/Trach, PZA (Art, PA, CVP), Time of respiratory **(These depend on the ventilator).**	Cm Numeric Scale(Air Entry) Scale Scale	0, 1, 2, 3 +, ++, +++ 1 2 3 M P B	
Monitoring parameters			
Monitoring systems	Number of different type of monitors.	0, 1, 2, 3, ... (positive integer)	ND
Monitor interfaces	Number of different monitor screens.	0, 1, 2, 3, ... (positive integer)	ND
Body temperature	The temperature measured on a patient's body.	°K or °C	98.6°F or 37°C
Cardiac/ECG	Heart Rate, Waveform, Diastolic BP,	Beats per minute (bpm)	from 60 to 100 lower than 80 (60)

	Systolic BP, Mean BP	mmHg mmHg	120-129 (110) (76,67)
Hemodynamics	PAP Pulmonary Artery Pressure RAP Right Atrial Pressure /CVP LAP Left Atrial Pressure /PCWP SVR Systemic Vascular Resistance /PVR MAP Mean Arterial Pressure	mmHg mmHg mmHg dynes · sec/cm5 mmHg	15 – 25 2-6 6-12 800 – 1200 70 – 105
ICP Monitoring (EVD)	MAP Mean Arterial Pressure ICP Intra Cranial Pressure CPP Cranial Perfusion Pressure CSF Drained CC: Cerebro Spinal Drained Level	mmHg mmHg mmHg Cubic Centimer Cubic Centimer	MAP = CPP – ICP = 70 – 10 = 60 5 to 15 (10) 60-80 (70)
EEG	Amplitude, Frequency, Spatial distribution Waveform	µV Hz	about 100 on the scalp delta (<3.5Hz) theta (4 to 7.5 Hz) alpha (8 to 13 Hz) beta (>13 Hz) monophasic, biphasic or polyphasic
SpO_2	Rate R/IR Percentage of oxygen Saturation	%	>95
$EtCO_2$		mmHg	35-45
	Blood test parameters		
Blood tests	Number of sample tubes required for the tests.	0, 1, 2, 3, … (positive integer)	
Type of blood test	**Chemistry:** Glu, Na, K, Cl, Bicarbonate, Urea, Creatinine, Ca, Mg, P, AST, ALD, ALP,	concentration mg/dL mEq/L mmol/L mEq/L mmol/L mg/dL mg/dL mg/dL mmol/L or mg/dL mg/dl U/L ng/dL U/L	https://webpath.med.utah.edu/EXAM/labref.htm [70:100] [135 :145] [3.6:5.2] [98:106] [23:29] [6:20] [0.9:1.3] ♂ [0.6:1.1] ♀ fr 18:60 yo [8.6:10.2] 0.6-1.1 or 1.46–2.68 3.4 to 4.5 14 - 59

	LD, Bilirubin, Albumin, Protein, Amylase, Troponin, Lactate, CK, Creatinine Kinase **Hematology:** Hb, Leucocytes, Platelest, Hematocrit, Neutrophils, Lymphocytes, Pro Time, INR, aPTT	U/L mg/dL g/dL g/dL U/L ng/mL mmol/L SI units/L mmol/L mmol/L /L mg/Dl mmol/L /L	2 - 9 50-100 300 - 600 less than 0.3 3.5 - 5.2 6.3 - 8.2 40-140 <0.4 0.5-1 ♂ 55-170 ♀30-135 ♂8.7-11.2 ♀7.4-9.9 135 – 145 150-400 x 10^9 6 and 20 135 – 145 1.0-4.0 X 10^9 https://mcc.ca/objectives/normal-values/
Pharmacology parameters			
Medication amount and types	Number of different types of medication and names	0, 1, 2, 3, … (positive integer) and name	[0:∞[
Maximal concentration (Cmax or Tmax)	C_{max} is the maximum serum concentration that a drug achieves in a specified compartment or test area of the body after the drug has been administered and before the administration of a second dose.	Unit of concentration	Drug-depended
Area under the concentration–time curve (AUC, 0–10 h)	The area under the curve (AUC) is the definite integral of a curve that describes the variation of a drug concentration in blood plasma as a function of time.	Unit of concentration	Drug-depended
Half-life (t1/2)	The time it takes for the concentration of the drug in the plasma or the total amount in the body to be reduced by 50%.	Units of time	Drug-depended

Elimination rate constant (Ke)	It is a value that describes the rate at which a drug is removed from the system.	Units of concentration	Drug-depended
Total body clearance (CL)	The total body clearance (ClT) is the sum of the renal clearance (see the record on Renal drug excretion), hepatic clearance, and clearance due to any other routes of elimination (respiratory, fecal, salivary, etc.). Clearance is a measure of the efficiency of the body to eliminate the drug.	Unit of concentration	Drug-depended
Dose of medication	Amount of medication taken at one time.	ml	Drug-depended
Dosage of medication	Frequency of doses over specific period of time.	0, 1, 2, 3, ... (positive integer)	[0:∞[
Side-effects of medication	Enter the observed and diagnosed side-effects of given medication.		Drug-depended
Drips/Drugs		mL/h	Drug-depend
Location and amount of drain	Location of drain on patient's body and the amount of drains used.	Areal description of body 0, 1, 2, 3, ... (positive integer)	Depends on the patient's conditions
Dialysis parameters			
Frequency of dialysis	Each time that we change the dialysis circuit.	0, 1, 2, 3, ... (positive integer)	Not determinable (depends on the patient) [0:∞[
Total duration of dialysis	Temporal description of the duration of dialysis application on patient.	Seconds, Minutes, Hours, Days	(Depends on the patient) [0:∞[
URR	Urea reduction ratio	%	>65
Kt/V	Another way of measuring dialysis adequacy • K stands for the dialyzer clearance, the rate at which blood passes through the dialyzer, expressed in		Below 1.2

	milliliters per minute (mL/min) • t stands for time • Kt, the top part of the fraction, is clearance multiplied by time, representing the volume of fluid completely cleared of urea during a single treatment • V, the bottom part of the fraction, is the volume of water a patient's body contains		
Other Neurologic parameters			
Pupil size	Diameter measured of pupils with variance of light brightness.	mm	from 2 to 4 mm in diameter in bright light to 4 to 8 mm in the dark
Reactivity of pupil	Pupil's accommodation to light changes.	Binary	Yes or No
Limb movement	Ability to move limbs.	Left or Right, Scale for Legs and Arms	Yes or No, 0, 1, 2, 3, 4, 5 Posturing F/E
Patient stats			
Damage (type, location, amount)	Observed and diagnosed patient's body damage type, location and the amount of damages.	Text	
Disease (type and state)	Diagnosed disease type and state of disease.	Text	
Patient type	Description of patient (pediatric, adult).	adult, pediatric	
Patient conditions	Description of diagnosed conditions.	Text	
Patient identity	Name, age, patient ID.	Text, number, number	Text, [0:120[, [0:∞[

Patient history	Available information on patient's history from GP, other hospitals and treatments.	Text	
Imaging setting			
Radiology (DICOM?)	Images taken (Scans etc.)	Image file	
Notes and Assessment			
Clinical notes	Notes taken by physicians to keep track of the requirements for further treatment.	Text	
Nursing Assessment	Patient assessment taken by nurses.	Text	
Staff parameters			
Medical staff (in ICU)	Number of nurses, therapists, physicians, radiologists, ...	0, 1, 2, 3, ... (positive integer)	ND
Support staff (in ICU)	Number of pharmacists, technicians, engineers etc.	0, 1, 2, 3, ... (positive integer)	ND
Years of experience	Time that shows how long a staff member has worked in a specific/related field.	0, 1, 2, 3, ... (positive integer)	
Type of diploma	Graduated degree of staff.	Nurse, pharmacist, physicians	
Important parameters			
Date	Day of the year.	Year/Month/Day	
Time	Clock time.	Hours, Minutes, Seconds	

References:

Ventilator Parameters : https://www.slideshare.net/sanilmlore/mechanical-ventilation-29439357

Hemodynamics: http://www.lidco.com/education/normal-hemodynamic-parameters/

Dialyses part : https://www.niddk.nih.gov/health-information/professionals/clinical-tools-patient-management/kidney-disease/identify-manage-patients/manage-ckd/hemodialysis-dose-adequacy

Annexe II - List of personas

PERSONAS	Primary Care Physician https://www.ehra.org/resource-library/personas/sharon-benton-md-primary-care-physician	Hospital Nurse https://www.ehra.org/resource-library/personas/carolyn-coolridge-rn-hospital-nurse	Medical Assistant https://www.ehra.org/resource-library/personas/mary-michaels-medical-assistant	Hospital Pharmacist https://www.ehealthireland.ie/Strategic-Programmes/Electronic-Health-Record-EHR-/Final-Persona-Scenario-files/Acute-HSP-Hospital-Pharmacist-Charlene-Hunter-v1-0.pdf
Name	Sharon Benton, MD	Carolyn Coolridge, RN	Mary Michaels	Charlene Hunter
Short presentation about them	42 years old; Married, two kids; Typically works 60 hours/week	45 years old; married, three children; BSN degree; Works four 10-hour shifts per week, plus occasional weekend overtime.	Age 35; Married, two children; Associate's degree, healthcare administration; Works full-time, Monday – Friday	40 years married with 2 young children MSc in Pharmacy
Tasks				• Log into HER • Take in charge new drug prescription • Need to check medication history • Inpatient prescription chart • Review the record of the patient • Communicate with the medical team through HER for recommendation

				• Complete pharmacological review
Short-term goals	• share information about my patients with other providers efficiently and easily • spend less time completing administrative or duplicative tasks • communicate effectively with patients • pay educational debt and support family. • a better work-life balance	• Ensure that all patients receive their medications and other treatments on time • Educate patients on a healthy lifestyle and observe the patient putting the education into action • Make sure each patient and family feels like they are getting the care and attention they need. • Organize the day to finish shift on time. • Complete all tasks. • Ensure patients are discharged in a timely manner • see and communicate easily each patient's plan of care	• Make a patient feel better today • Get all the patients out on time today • Document the most accurate patient information • Help patients access the right information about their treatment plans • Get additional EHR[3] training to increase workflow efficiency.	• Counsel the patients on the safe use of prescribed products • Participate in departmental audits
Long-term goals	• provide high-quality care for patients	• Become proficient in customizati	• Go back to school to	

[3] E.H.R.: Electronic Health Record

	consistently, see improvements in their outcomes, and help them stay healthy. • Identify new revenue opportunities at the practice and participate in an advanced care team solution • Identify more ways that technology can be used in the practice to save time or improve processes, workflows and tasks. • Become a totally **paperless medical practice** in the next two years.	on and optimization of EHR to improve daily workflow. • Seamlessly capture data during routine provision of care • Stay up-to-date on continuing education required to maintain RN licensure every two years. • Develop and implement a training program for new graduates and other nurses new to our unit to help them get up to speed more quickly and efficiently.	become a nurse • Create an environment that makes our office run more smoothly and makes patients feel more comfortable.	
Typical problems	• Spend 2–4 hours every day after work completing EHR tasks • The practice cannot keep exam rooms full, because of completing the post-visit quality reporting tasks	• Staffing shortages can put nurses at greater risk for patient safety issues. • Unable to locate patient records in one place. • High percentage	• Don't feel efficient with this EHR • Must cater to each doctor's work habits and documentation styles. • Possibilities for errors.	• Frustration because of the lack of computers on the wards • Not having enough time to provide safe and effective cover on the wards as well as

	required for each patient. • Daily frustrations when interacting with the EHR system because of many clicks required for frequently used workflows, navigation is difficult, and the system does not organize the data in an efficient way • Prior authorization and other payer-imposed roadblocks contribute to inefficient care delivery for both clinicians and patients. • Patients with multiple chronic conditions can be very difficult to care for.	of nursing burnout, with nurses leaving the patient care workforce in favor of non-direct patient care types of nursing. • Unable to speak to some patients without interpreter due to language barrier. • Difficulty communicating with healthcare team efficiently • Spend a lot of time recording large amounts of information and completing documentation. • Common tasks can be laborious (too much clicking). • The doctor keeps reconciling the meds incorrectly, further lengthening the time required to	• Interruptions and distractions. • Inexperienced staff/high turnover. • Wear too many hats. • Spend a lot of time with tasks that should be faster/easier.	undertake her dispensary duties

		discharge patients. • Rarely doing one task at a time and constantly interrupted. • pressure and fatigue • no consistency. • Misuse from other nurses of HER (completing the same info in a different part) • Complex tasks • Medication managemen t • Can't easily see what is missing or what hasn't been done, particularly around documentati on. • Lack of investment in daily patient because of dissatisfacti on of job • Injuries		