



UNIVERSITÀ DEGLI STUDI DI NAPOLI  
**FEDERICO II**

**itee** PhD  
information technology  
electrical engineering



# Danilo Calderone

## Innovations in Pediatric Healthcare: 3D Printing and Telemedicine

Tutor:

**Prof. Mario Cesarelli**

Cycle: 37th

co-Tutor:

**Prof. Fabrizio Clemente**

Year: Third



# Candidate's information

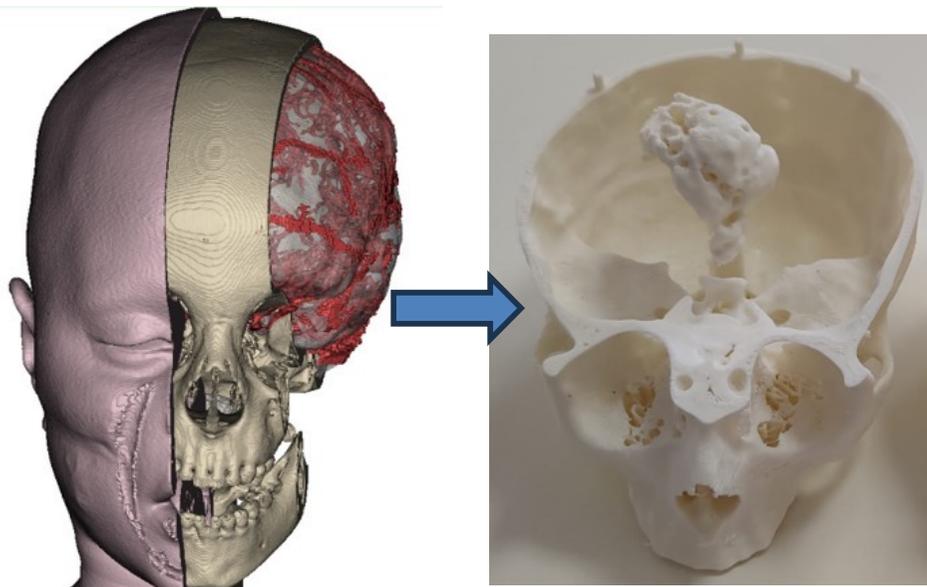
- Biomedical Engineering MSc degree in October 2021 in University of Naples “Federico II”
- PhD start date 01/01/2022 – end date 31/12/2024
- Scholarship type: PON MUR
- Periods in company: Santobono Innovation Srl (10 months)
- Periods abroad: Reykjavik University, Iceland (6 months)

# Research areas

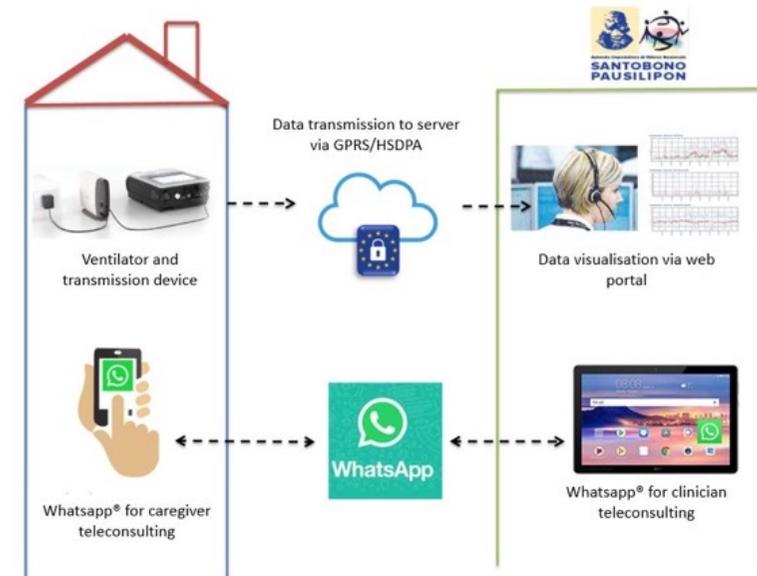
## Innovations in healthcare

Two main research topics

### 3D Printing for healthcare



### Telemedicine



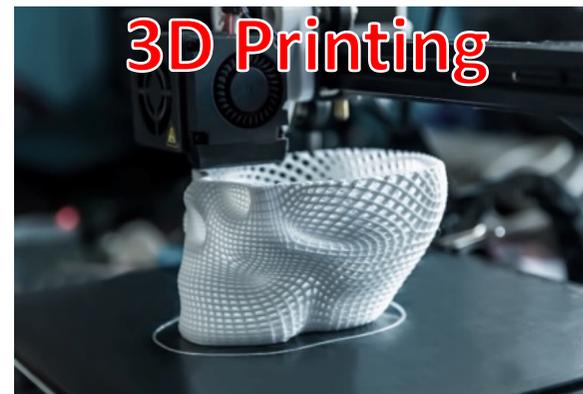
# Research activity: 3D Printing for healthcare

## Research Problem

### *Personalization of Clinical Solutions*

### *Application difficulties*

- Standard devices are often inadequate for patients, especially pediatric ones
- Need for personalized solutions for delicate pathologies (i.e. hip dysplasia, brain lesions)
- Use of standard devices are often very expensive and require high production time
- Production and disposal of standard devices produce a lot of wastes



# Research activity: 3D Printing for healthcare

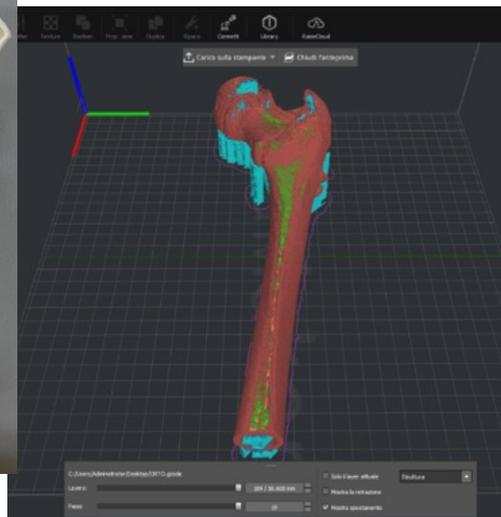
## Two main medicine fields of application

### *Pediatric Orthopedics*

*3D printed patient-specific anatomical models used for surgical planning and surgery simulation of orthopedic surgeries*

### *Pediatric Neurosurgery*

*Combination of Neuronavigator, MRI-guided Laser Interstitial Thermal Therapy and 3D printed patient-specific anatomical models for brain surgery simulation*



# Research activity: 3D Printing for healthcare

## *Improvements 3D printing workflow*

*Improvement of 3D printing process of anatomical models for the implementation in standard clinical treatment*



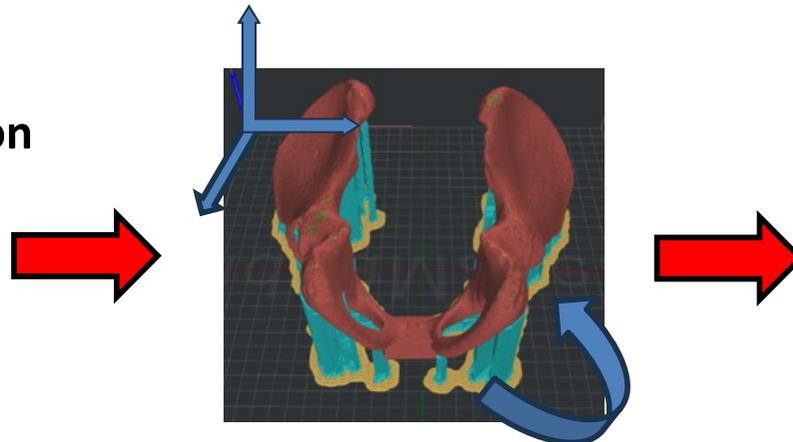
Despite the **numerous advantage**, clinicians still **do not** consider 3D printing as a valid strategy in patient treatment.

Among the limitations of 3D FDM printing technology, particularly crucial is the **high printing time**

Solution: **Printing workflow optimization**

**Orientation optimization**  
(position + rotation)

**Parameter optimization**



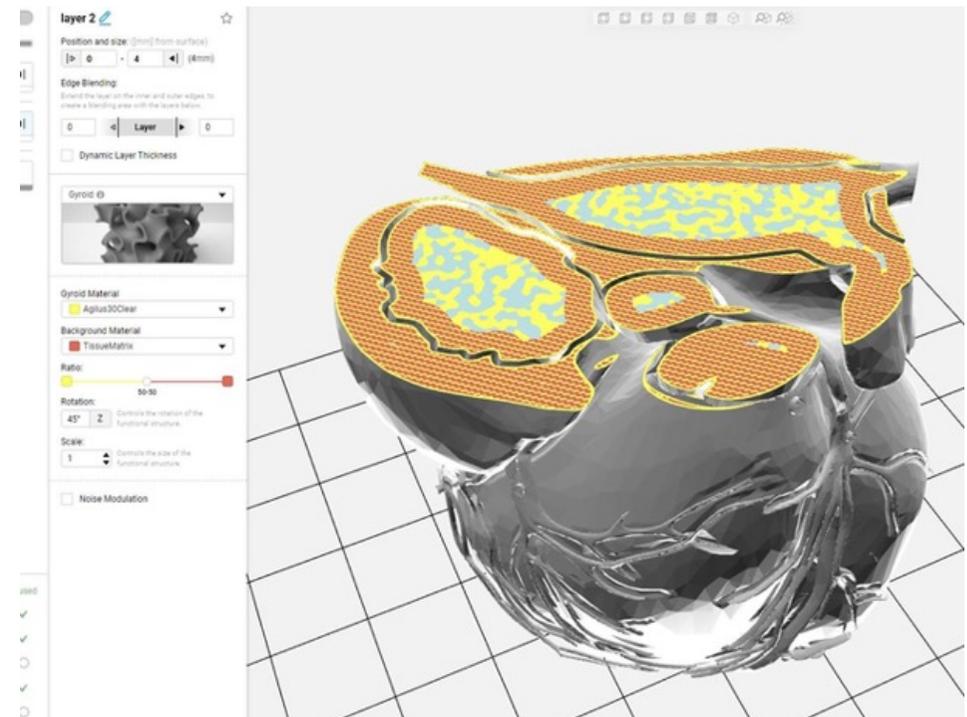
Danilo Calderone – YEP

# Research activity: 3D Printing for healthcare

## *Bio-Mimetic 3D Printable Human Anatomies*

The current limitations in anatomical model printing is the struggle to **replicate the exact mechanical responsiveness of human anatomical structures**

In collaboration with **Reykjavik University**, a study was started for creating models that not only look like human tissues but also replicate their mechanical properties



# Research activity: Telemedicine

## Research Problem

- **Geographical Barriers**

Patients in remote or rural areas struggle to access specialized care

- **High Costs**

Travel expenses, extended hospital stays, and logistical inefficiencies increase healthcare costs

- **Reduced Patient Burden**

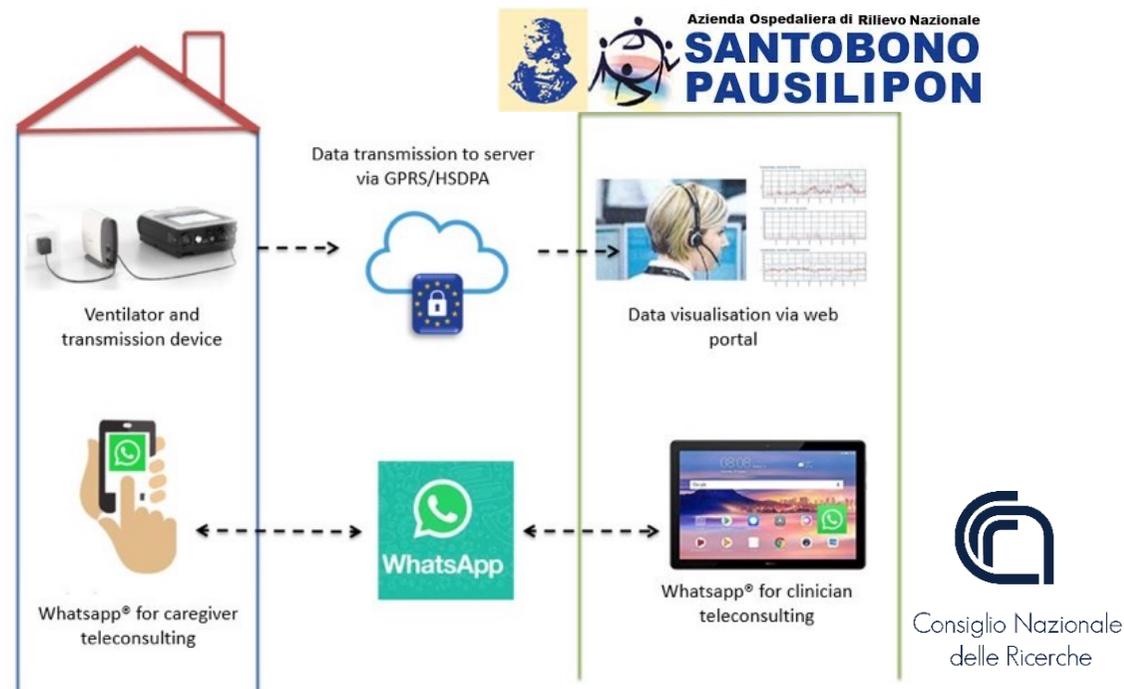
Frequent in-person hospitalizations can disrupt patients' quality of life



# Research activity: Telemedicine

## Management, Quality measurement and technological research in the field of telemedicine

*Guardian Angel: a telemonitoring project for pediatric patients on home pulmonary ventilation*



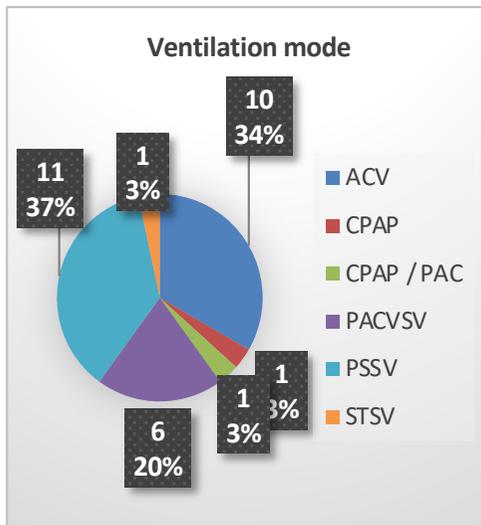
# Research activity: Telemedicine

## Characterization of “Guardian Angel” telemonitoring service

### Data gathering and analysis

Number of patients enrolled: **30**

- Obtainment of mechanical and clinical data from the telemonitoring cloud platform
- Evaluation of initial statistics based on the pathology and the therapy settings
  - Evaluation of outliers by clinical-mechanical definition



	STRUCTURE	PROCESS	OUTCOME	Dati monitorati											
				Trigger spontaneo (%)				Ciclo Spontaneo (%)							
				10/11	2/23	3-15	11/3/23	10/11	2/23	3-15	11/3/23				
	AORN Santobono-Pausilipon, Service center	Telemonitoring and Teleassistance of home-assisted patients with chronic respiratory diseases	Measure of telemedicine service effects on the AORN and the caregivers	/	/	3,00	/	/	/	0,00	/	/	/	/	
	<b>Complexity</b> • Type and number of professional figures involved in the provision of the service (Medical Specialist, Nurse, etc.). • N°. of operators involved in providing the service / No. of users. • Devices and ICT resources.	<b>Process size</b> • N°. of users followed in the last 9 months / No. of users followed in the previous 9 months. • Target coverage (%): Percentage of users followed out of the total number of users affected by the pathology covered by the service in the area of interest. • Average size: average number of contacts / month average number of contacts / month per user	<b>Efficacy</b> • N° of re-hospitalizations for acute cases among users followed in Telemedicine in the last 9 months • Average days of hospitalization in the last 9 months per user followed in Telemedicine • Average time of home visits with telemedicine in the last 9 months (television duration) • N° acute situations (non-compliance, abnormalities) detected with the telemonitoring service in the last 9 months • Absolute Drop-Out: N° of users who leave the Telemedicine path by choice / 6 months • Relative Drop-Out: N° of users who leave the Telemedicine path by choice / 6 months	35,00	38,00	35,00	47,00	79,00	72,00	77,00	68,00	0,00	1,00	1,00	0,00
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# Research results

## ***3D Printing***

- 3D Printed anatomical models can improve the overall clinical treatment, reducing operating time and improving the clinical outcome
- More advantages from 3D printing when treating pediatric patients due to their body in continuous growth

## ***Telemedicine***

- Telemonitoring can improve patients' Quality of Life and reduce the burden of clinicians and caregivers
- Monitored data can give informations about the clinical state of children

# Summary of research activities

## Events and conferences

**MetroXRINE Conference 2023**, 25<sup>th</sup> - 27<sup>th</sup> October, Milan (Italy)

**MetroXRINE Conference 2024**, 21<sup>th</sup> - 23<sup>th</sup> October, St. Albans (UK)

**E-Health and Bioengineering (EHB) Conference 2023**, 9<sup>th</sup> – 10<sup>th</sup> November, Iasi (Romania)

## Ad Hoc PhD courses

Biosignal and Postural Control: BioVRSea

Academic Entrepreneurship

Using Deep Learning Properly

3D printing and advanced 3D printing courses *...and others*

## Period completed

Period in company completed: **10 months**

Period abroad completed: **6 months**

## Awards and Prizes

Participation to **StartCup Campania 2024**  
**3<sup>rd</sup> Place!**

# Research products

[P1]	Dolcini, A., Iuppariello, L., Calderone, D., Cesarelli, M., & Clemente, F. <b>“Guardian Angel 2.0: A telemedicine service for children with home mechanical ventilation”</b> , <i>Revue Roumaine Des Sciences Techniques Série Électrotechnique Et Énergétique</i> , vol. 67.3: pp. 355-358. 2022
[P2]	Iuppariello, L., Calderone, D., Casaburi, A., Romano, G., Guida, P., & Clemente, F. <b>“Use of three-dimensional printing technology for supporting the hip reconstruction surgery in paediatric patients”</b> , <i>Discover Applied Sciences</i> , vol. 6(2), p. 44
[P3]	Calderone, D., Cesarelli, G., Ricciardi, C., Amato, F., & Clemente, F. <b>"3D printing application for orthopedic pediatric surgery—a systematic review"</b> <i>Rapid Prototyping Journal</i> Vol. 30(11), pp. 275-287

# Research products

[C1]	<p>Calderone, D., Cesarelli, G., Cesarelli, M., Iuppariello, L., Guida, P., Casaburi, A., ... &amp; Clemente, F.</p> <p><b>“Optimization of 3D Fused Deposition Modeling Printing Process For the Manufacturing of Devices For Medical Use”</b></p> <p>Presented at 2023 IEEE International Conference on Metrology for eXtended Reality, Artificial Intelligence and Neural Engineering (MetroXRINE), Milan, Italy</p>
[C2]	<p>Calderone, D., Cesarelli, G., Iuppariello, L., Mirone, G., Cinalli, G., Amato, F., &amp; Clemente, F.</p> <p><b>“Applications of 3D Printing and Neuronavigation in Neurosurgery: a Literature Review and a Clinical Case Report”</b></p> <p>Presented at E-Health and Bioengineering (EHB) 2023, 9/11-10/11, Iasi, Romania (Online participation).</p>
[C3]	<p>Angelone, F., Ponsiglione, A. M., Andreozzi, E., Calderone, D., Cesarelli, G., Amato, F., &amp; Romano, M.</p> <p><b>“3D Dental Reconstruction with Photogrammetry Technology”</b></p> <p>Presented at 2023 IEEE International Conference on Metrology for eXtended Reality, Artificial Intelligence and Neural Engineering (MetroXRINE), Milan, Italy</p>

# PhD thesis overview

- **Thesis title**

Innovations in pediatric healthcare: 3D Printing and Telemedicine

- **Two main fields**

*3D Printing and Telemedicine in healthcare*

- **Objective**

To explore these technologies applications in healthcare to both adults and pediatric patients, evaluating advantages and disadvantages compared to traditional procedures

- **Methodology**

Introduction in the hospital of Naples «Santobono-Pausilipon; Literature review

# PhD thesis

## Chapter I – Introduction

In this chapter both these technologies will be introduced, focusing on its impact in the years and mentioning some of the advantages already presented in literature as a general overview

Content of the successive chapters will be presented

# PhD thesis

## Chapter II – 3D Printing

- Introduction on 3D Printing in healthcare
- Introduction on 3D Printing for pediatric patients
- Use of 3D Printing for pediatric orthopedics
- Use of 3D printing for pediatric neurosurgery
- Limits and related improvements of the workflow
- Advanced 3D Printing for mechanical reproduction

# PhD thesis

## Chapter II.3 - Use of 3D Printing for pediatric orthopedics

- Presenting a literature review on the theme
- Presentation of 3D printing applications for the treatment of hip diseases in pediatric patients of «Santobono-Pausilipon»
  - Description of the workflow used for the fabrication
  - Evaluation of advantages and disadvantages based on questionnaires proposed to surgeons
- Presenting other application examples (anatomical models) printed for surgeons not published
- Overall results: Highly detailed models, surgical time and blood loss reduction



# PhD thesis

## Chapter II.4 - Use of 3D Printing for pediatric neurosurgery

- Presenting a literature review on the theme
- Presenting a study on the use of 3D printing in combination with neuronavigator and Mg-LITT for medical education and surgery simulation
  - Description of the workflow used for the fabrication
  - Evaluation of advantages and disadvantages based on questionnaires proposed to trainers and trainees
- Presenting other application examples (anatomical models) printed for surgeons not published
- Overall results: Highly detailed models, useful in knowledge transfer and medical training



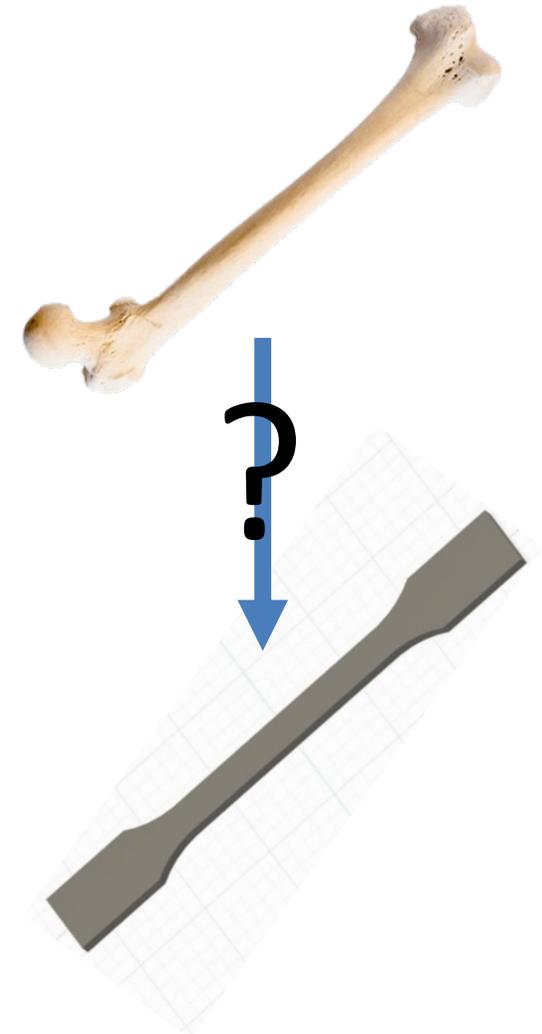
# PhD thesis

## Chapter II.5.1 – Optimization of the printing workflow

- Addressing in a presented study the limits found in literature and in my experience of the 3DP workflow
- Evaluation performed comparing results between traditional workflow and optimized workflow (i.e. printing time)

## Chapter II.5.2 – Advanced 3DP for mechanical behavior reproduction

- Presenting with a study carried out **in collaboration with Reykjavik University** focused on using 3DP for reproduction of mechanical behavior of biological tissues



# PhD thesis

## Chapter III – Telemedicine

- Introduction on Telemedicine
- Introduction on Telemedicine for pediatric healthcare
- The telemonitoring project «Guardian Angel» in the hospital of Naples «Santobono-Pausilipon»
- Quality measurement and data analysis of «Guardian Angel»

# PhD thesis

## Chapter III.4 – Quality measurement and data analysis of «Guardian Angel»

- Presentation of the quality indicators and of the study behind them
- Presentatio of the results from the quality indicators
- Presentation of the data analysis and related raw results

<u>STRUCTURE</u>	<u>PROCESS</u>	<u>OUTCOME</u>
<b>AORN Santobono-Pausilipon, Service center</b>	<b>Telemonitoring and Telessistance of home-assisted patients with chronic respiratory diseases</b>	<b>Measure of telemedicine service effects on the AORN and the caregivers</b>
<p><b>Complexity</b></p> <ul style="list-style-type: none"> <li>• Type and number of professional figures involved in the provision of the service (Medical Specialist, Nurse, etc.).</li> <li>• N°. of operators involved in providing the service / No. of users.</li> <li>• Devices and ICT resources.</li> </ul>	<p><b>Process size</b></p> <ul style="list-style-type: none"> <li>• N°. of users followed in the last 9 months / No. of users followed in the previous 9 months.</li> <li>• Target coverage (%): Percentage of users followed out of the total number of users affected by the pathology covered by the service in the area of interest.</li> <li>• Average size: average number of contacts / month average number of contacts / month per user</li> </ul> <p><b>Process stability</b></p> <ul style="list-style-type: none"> <li>• Duration: N°. of months of activity from the activation of the service</li> </ul> <p><b>Operational efficiency</b></p> <ul style="list-style-type: none"> <li>• N° of hours of use of the service / N°. of professionals involved.</li> </ul>	<p><b>Efficacy</b></p> <ul style="list-style-type: none"> <li>• N° of re-hospitalizations for acute cases among users followed in Telemedicine in the last 9 months</li> <li>• Average days of hospitalization in the last 9 months per user followed in Telemedicine</li> <li>• Average time of home visits with telemedicine in the last 9 months (television duration)</li> <li>• N° acute situations (non-compliance, abnormalities) detected with the telemonitoring service in the last 9 months</li> <li>• Absolute Drop-Out: N° of users who leave the Telemedicine path by choice / 6 months</li> <li>• Relative Drop-Out: N° of users who leave the Telemedicine path by choice / 6 months</li> </ul>

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# PhD thesis

- **Chapter IV – Discussions and Conclusions**
  - Defense of the results of chapter III and chapter IV, also considering related literature
  - Overall discussions of these applications in healthcare
  - Conclusion of the thesis

# PhD thesis

## Innovation

Applications in **pediatric** healthcare

## Conclusions

**3D Printing and Telemedicine** can drastically improve the traditional approaches for pediatric healthcare