Senses & Sensibility'21

Designing Next Genera(c)tions

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Curb the environmental impact of hospitals through the redesign of single-use procedural kits

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The current pandemic crisis has highlighted how the excessive use of plastics in hospital systems is one of the most critical issues in terms of recovery, recycling and proper disposal of the waste generated by the entire system. In an attempt to respond to this crucial question, the paper reports on research conducted on single-use surgical products, in particular on the redesign of a single-use procedural kit. The research was conducted through desk research, field research and the HCD approach. The research required a multi-disciplinary approach to develop new sustainable layouts starting with the details, requirements and needs for the design of an adaptable and versatile procedure kit were highlighted. The design solutions that led to the realisation of the prototype are: design of a biodegradable EPP tray, functional for disposal by incineration; design of a recyclable PETG tray, divided into 3 compartments. The project will reduce production costs by using less plastic material, leading to the creation of a new product/service flow; organic-based tray that minimises pollution; reducing incineration by reducing unused waste; time-saving benefits by individual packaging of additional customisable instruments.

Keywords *Sustainable Healthcare*, *Waste consumption*, *Medical Packaging*, *Procedural kit*, *Circular Economy*

Introduction

Climate change is considered unstoppable with melting glaciers, rising seas and increasingly frequent and destructive rainfall and weather events (European Commission, 2017). The issue of global health care due to the ongoing pandemic has been found to be in small part, though currently intense, threatened by the impact of medical disposables both in global hospital facilities and in the home, such as surgical masks and medical gloves. Although very different in scale, each nation's healthcare sector directly and indirectly releases greenhouse gases during the delivery of care and use of products, services, and technologies from a high-carbon intensity supply chain (Karliner, 2019). Healthcare contributes to carbon emissions through energy consumption, transport, and product manufacture, use, and disposal (Practice Greenhealth, 2019). Therefore, it is necessary to change to a healthcare circular economy by adopting new sustainable practices necessary to curb the carbon footprint produced by this sector. Considering carbon emissions produced by the healthcare sector: if healthcare were a nation, it would be the fifth largest emitter of greenhouse gases on the planet (Karliner, 2019). It is a carbon contribution equal to the emissions of 514 coal-fired power plants, or 4.4% of global net emissions (Ngo, 2020). The highest contributions to the global healthcare climate footprint come from the United States (546 million metric tons of CO2e), China (342 MtCO2e), and the European Union (248 MtCO2e) (Karliner,2019). In 2012 the National Academy of Medicine estimated the U.S. healthcare system squandered $765 billion a year, more than the entire budget of the US Defence Department (Allen, 2017). In the University of California, San Francisco Medical Center, for instance, researchers estimated that in a single year the hospital wasted $2.9 million in neurosurgery supplies alone. On wasted supplies in just one department (Allen, 2017).

Through a specific case study, this study aims to analyse the current situation in the healthcare sector, which is an influent producer of circular plastic stream waste, and to introduce possible sustainable alternatives reconfiguring inserts with macro division of items unused in a neurosurgical procedural kit.

Challenges and opportunities for a circular healthcare system

Over the years many communities worked to fight carbon emissions produced by healthcare facilities, promoting recycling, reusing, recovering and new management strategies. Healthcare Plastics Recycling Council (HPRC) has led projects to develop hospital waste diversion strategies, but single-use plastics still dominate in healthcare environments. At last count, about 2,800 to 3,500 tonnes of plastic packaging and plastic product waste from US healthcare facilities is generated daily, according to the HPRC. Most of this goes to landfill or is incinerated (Danigelis, 2020). Moreover, the ongoing health emergency has highlighted one of the critical factors in the sector: the environmental impact that determines the massive use of "disposable" products, which now are mainly based on the use of plastic polymers that are difficult to recycle and/or compostable.

In Italy, in terms of the amount of such medical waste, according to the Italian National Institute for Environmental Protection and Research, the numbers generated by the sanitation emergency would amount to a number between 150 thousand and 450 thousand tons (ISPRA Report, Waste consisting of used PPE, May 2020). Waiting to know what the final balance will be, according to Ecocerved, a consortium company of the Italian Chamber of Commerce system, in 2018 the Italian production of medical waste stood at around 180 thousand tons. Mostly, such waste is hazardous with infectious risk (78% of the total), coming from public hospitals, especially medium-large sized ones (almost 60% from public centres with at least 150 beds). At a national level, medical waste has no other destination than incineration, for 65% of the total, and activities aimed at disposal for the remaining 35%, with percentage differences between region and region (Ecocerved, 2020). From an economic point of view, operating rooms represent the greatest revenue and at the same time they are most of the waste comes and consequently "the greatest costs for disposal, accounting for 30% of the total amount of hospital waste" (Babu, 2019). Considering the collection and disposal of medical waste, there are tools that have to be disposed of immediately, while others can be recycled over a longer period of time, with the help of specialized organizations like Stryker, a recycling company for the medical industry items, or Vanguard Medical, a surgical instruments reprocessing company. Materials that are accepted by these organizations include laparoscopic devices, wristbands used for blood pressure measurement, surgical product casings and more. For supplies or equipment that are no longer useful but have not expired and are still in working order, they are collected by organizations such as Med Share who, after collecting them, distribute them to medical facilities that cannot afford to purchase these items probably due to cost (Tine Health, 2017). Hospitals implementing environmental initiatives in operating rooms saved more than $53 million in aggregate in 2018, with a median savings of over $100,000 per facility. (Practice Greenhealth, 2019).

A valuable example is the Johns Hopkins Health System in Baltimore, where the Neurasthenia Division was able to save

European Commission. (2017). Climate change consequences. Climate Action - European Commission. Retrieved from February 16, 2017. https://ec.europa.eu/clima/change/consequences_en

Karliner, J., Slotterback, S., Boyd, R., Ashby, B., & Steele, K.. (2019). Health Care Without Harm & Arup. Findings Health care's climate footprint. Health care's climate footprint (Climate-smart health care series Green Paper Number One) 10, 19. https://noharm-uscanada.org/ClimateFootprintReport

Practice Greenhealth. (2019) 2019 sustainability data. Practice Greenhealth. https://practicegreenhealth.org/tools-and-resources/2019-sustainability-data.

Ngo, H. (2020). How do you fix healthcare's medical waste problem. Coronavirus has made medical waste more visible than ever, but the environmental footprint of healthcare goes much further – and reducing it could save lives. BBC. https://www.bbc.com/future/article/20200813-the-hidden-harm-of-medical-plastic-waste-and-pollution

Allen, M. (2017). What Hospitals Waste. ProPublica. https://www.propublica.org/article/what-hospitals-waste

Danigelis, A. (2020). Healthcare Packaging Manufacturers Struggling with Sustainability. Environment + Energy Leader. Environmental leader. https://www.environmentalleader.com/2020/03/healthcare-packaging-struggle/

ISPRA. (2020). Report, Waste consisting of used PPE, May 2020. Retrieved from December 1, 2020. https://www.isprambiente.gov.it/files2020/notizie/rapporto-ispra-dpi-usati.pdf

Ecocerved. (2020). Report, Production of medical waste in Italy, 2020. Retrieved from December 1, 2020. https://www.ecocamere.it/dettaglio/notizia/451/rifiuti-sanitari-qual-e-la-situazione-in-italia

Babu, M. A., Dalenberg, A. K., Goodsell, G., Holloway, A. B., Belau, M. M., & Link, M. J. (2019). Greening the operating room: results of a scalable initiative to reduce waste and recover supply costs. Neurosurgery, 85(3), 432-437. https://doi.org/10.1093/neuros/nyy275

$5 million in 2010 and 2013 for its reprocessing program. But recycling is not always applicable for all items in the operating room; especially if there is a risk of infection. Patient safety is more important than sustainability (Tine Health, 2017). The key to minimising and effectively managing medical waste is the separation and identification of waste. Proper handling, treatment and disposal reduces costs and is very helpful in protecting public health. The most appropriate way to identify categories of medical waste is to sort the waste through the use of color-coded plastic bags or containers. Using the biohazard symbol on the packaging medical waste can be immediately identified from users (World Health Organization, 2019). From the above data, a clear picture emerges that highlights the contemporary incompatibility between the health need to use disposable plastic tools and packaging and the environmental need to reduce products with high polluting potential. This poses a challenge to the Design Discipline that research must be able to face to develop new practical, real, and sustainable solutions.
The research adopted needed a multi-disciplinary tactic to develop new sustainable layouts starting from the users need (usability) and hospital needs (economic sustainability). The research work objective was to reduce the waste of the disposable surgical instruments, contained in the trays that are usually used during several surgical procedures and that are often discarded without being used completely, because they are no longer sterile and unrecoverable. For this reason, the focus has been directed towards the major users of hospital disposable procedural kits having a significant impact both quantitatively and qualitatively. The objectives have contributed to the research and the definition of a specific sector in which to investigate.

Methods

To answer to this challenge, this paper reports research conducted on single-use surgical products, particularly on the redesign of a single-use procedural kit, using the Human-Centered Design approach and through both desk research and field research (Fig. 1). Starting from an analysis of the scientific literature, aimed at two parallel aspects with a strong impact on the hospital economic system, have been tackled critical issues on surgical supplies packaging, saving on products, transport and waste production. From a quantitative point of view, a study was aimed to highlights which and how many materials are most unused in an operating theatre, where up to 70% of hospital waste is created, and up to 90% of operating room waste is improperly sorted and sent to costly and unneeded waste processing (Lee, 2012). A best practice adaptable has been described

Practice Greenhealth. (2019) Ibidem

World Health Organization. (2019) Safe management of wastes from health-care activities II. Retrieved from May 6, 2021. https://www.who.int/water_sanitation_health/publications/wastemanag/en/

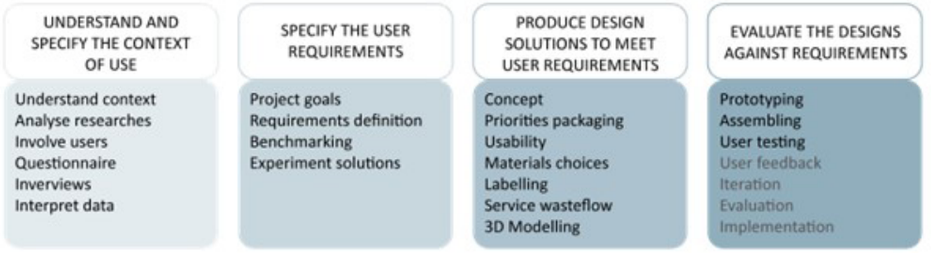


Figure 1: Design Process

Lee, R. J., Mears, S. C. (2012). Greening of orthopedic surgery. Orthopedics, 35(6), e940-e944.

Circle Economy (2015). Healthcare Plastic Waste: Analysis of OLVG Hospital Plastic Waste Streams. Amsterdam. https://www.circulairondernemen.nl/uploads/669c6eb7189f26e44986a9ef69c15569.pdf

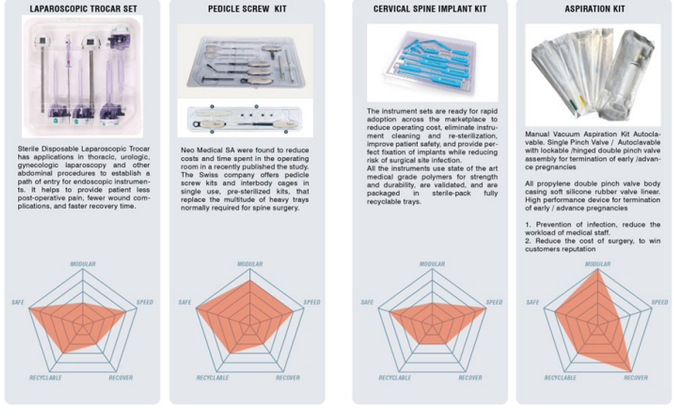
Zygourakis, C. C., Yoon, S., Valencia, V., Boscardin, C., Moriates, C., Gonzales, R., & Lawton, M. T. (2017). Operating room waste: disposable supply utilization in neurosurgical procedures. Journal of neurosurgery, 126(2), 620-625. https://doi.org/10.3171/2016.2.JNS152442

by the Nederland Circulair initiative of the Dutch Ministry of Infrastructure and Environment that contributed to the overall objective of creating a single stream of plastic packaging in hospitals by analysing the typical plastic waste streams of the OLVG hospital. “The largest category of plastic products found in OLVG hospital waste bags is single-use packaging, which accounts for more than 50% of the total plastic waste”. (Circle Economy, 2015). Moreover, from a qualitative point of view, the research paid attention to what may be the biggest economic wastes within operating theatres, identifying real waste of disposable instruments that are not always used during certain surgical procedures consequently creating a significant burden on healthcare costs. Related is a study published in the Journal of Neurosurgery, Dr Corinna Zygourakis, a leading neurosurgeon at the University of California, San Francisco, said that "accounting for the different case distribution in the 58 selected cases, the authors estimate approximately $968 of OR waste per case, $242,968 per month, and $2.9 million per year, for their neurosurgical department” (Zygourakis, 2017). Analysed the context phase, user research has been carried out with an overview of the different roles of nurses within the operating room. Subsequently, user requirements were defined, obtained by submitting a questionnaire to surgeons and instrument nurses working in the different sectors, which were highlighted all the peculiarities, both positive and negative, of disposable surgical supplies. The questionnaire was completed by 11 surgeons from different hospital departments, suggestions or considerations were asked about the issues submitted (Fig. 2).
One general surgeon, in the gallbladder procedure, advised to "open only what is necessary to start the procedure, and then the rest". Another surgeon from obstetrical traumatology suggested "bagging the disposable material individually, so that it can be opened when needed". The aim was to identify the areas of use and any waste that occurs within an operating theatre,

Figure 2: The operating block of Orthopaedics.

regarding disposable instruments that, although opened within the operating protocol, are not used, paying particular attention to those instruments that have a greater risk of falling/breakage. A benchmarking has been carried out by collecting data on the different types of packaging for medical devices and disposable instruments with the aim to highlight interesting specific characteristics, functional to develop the product (Fig. 3). The latter defined the various needs and showed how some of them respond to certain needs such as considerable waste and safety priorities. The research was then carried out in the field through visits that led to observations within the operating block of Orthopaedics. An interview with the head of the operating theatre department and a neurosurgeon trainee allowed a comparison of which procedures could be optimised and suggestions on how to identify instruments that were more or less used and more or less at risk. Prior to defining the requirements, a task

Figure 3: Scenario Analysis.



analysis was carried out to identify the sequence of actions that operators perform during a surgical procedure using disposable kits (Figure 4). It was ascertained that on several occasions the following dynamics occurred:

- Fall of a disposable instrument, leading to the opening of a second kit for the rapid continuation of the procedure
- Breakage of a disposable instrument, leading to the opening of a second disposable kit for a single instrument
- Non-use of some instruments in the disposable kit in most of the cases analysed.

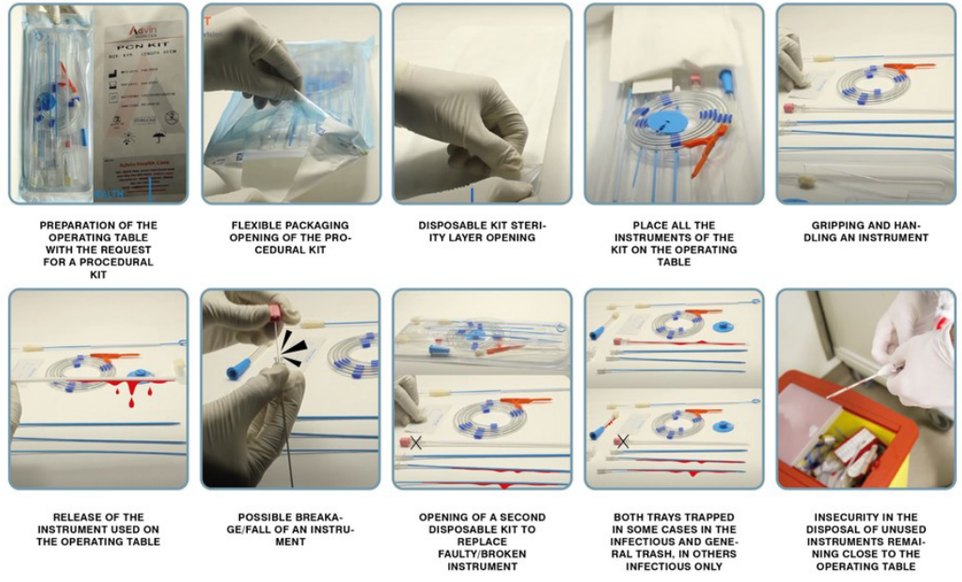
Subsequently, the following were identified specific requirements adaptable to many different procedures that can optimize the lifecycle products:

- a smart labelling that describes the proper disposal,
- the shelf-life efficiency,
- packaging choice on the number of plastic barriers needed for a specific device/tool,
- the shock resistance ensuring durability and sterility and
- a proper sizing to optimize the supply chain

Results

The design solutions that led to the realisation of the prototype were a) the design of a biodegradable EPP tray, functional

Figure 4: Storyboard.

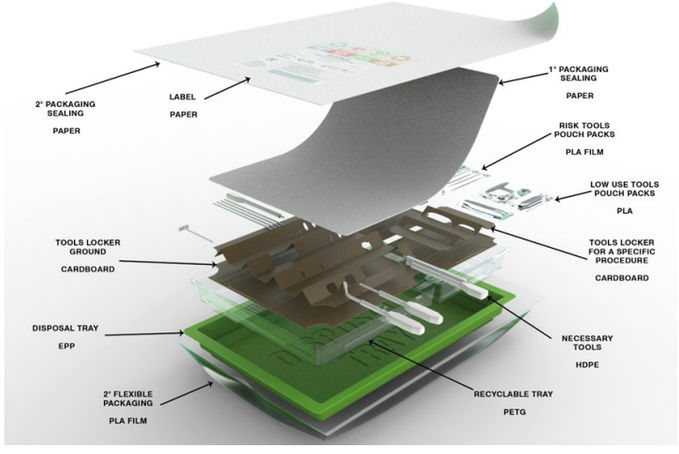


for disposal by incineration; b) the design of a recyclable PETG tray, divided into 3 compartments (Figure 5). The biodegradable EPP tray collects all the instruments used during the procedure, therefore infected, with the end of their lives being incineration. The recyclable PETG tray contains in turn three specific compartments. The first contains instruments that need to be ready to use, the second at risk of falling/breaking, and the third instruments that are not always used. Those are fixed on a cardboard layer that replaces the individual compartmentalisation per instrument, making the kit customisable for any type of single-use procedure, as well as being able to make the PETG tray sterile (Fig. 5). The design of "EcoPack" medical packaging resulted from a creation of a new product/service flow focused on:

- returning the packaging to the manufacturer of those packages by locating them in the additional tool tray, so they are not necessarily ready to use;
- reducing the amount of biohazard waste burned in the incinerator. The use of an organic-based tray aims to minimise site pollution;
- advantageous recycling for trays and procedural tools that were previously rejected in general, waste or even biohazard waste.

To validate the design proposal in terms of usability and effectiveness of the created system, some Human-centered Design tools were used such as the Task Analysis, the representation of use scenarios, and the creation of a live simulated photographic storyboard thanks to the participation of medical staff already involved in the early stages of the research.

Figure 5: EcoPack configuration.



Abdalla, Y. (2020). Value based healthcare: Maximizing efficacy and managing risk with spinal implant technology. Interdisciplinary Neurosurgery, 22, 100810. https://doi.org/10.1016/j.inat.2020.100810

Conclusions

In conclusion of the research part, a single use procedural tray was redesigned, taking as example the Neo Pedicle Screw System™, Neo Medical S.A. (Abdalla, 2020). The concept reveals a kit containing the necessary instruments, all in one package, and customisable single-package instruments. The tray is optimised by selecting the instruments used, only in special situations or overused and therefore at risk of falling/breakage. The design solutions that led to the realisation of the prototype were:

- the design of a biodegradable EPP tray, functional for disposal by incinerators,
- the design of a recyclable PETG tray, divided into 3 compartments.

The biodegradable EPP tray collects all the instruments used during the procedure, therefore infected, with the end of their lives being incineration. The recyclable PETG tray contains in turn three specific compartments. The first contains instruments that need to be ready to use, the second at risk of falling/breaking, and the third instruments that are not always used. Those are fixed on a cardboard layer that replaces the individual compartmentalisation per instrument, making the kit customisable for any type of single-use procedure, as well as being able to make the PETG tray sterile. All those points are summed up on Fig. 6. In the next phase, there was the opportunity to get in touch with a resident neurosurgeon and the head of the operating block of the hospital in Rome, who provided valuable elements for the realization of the prototype, offering his experience in the operating room and allowing me to optimize the functionality of the product made. In the opinion of many of the people involved, the feedback and interest received are likely to be developed in the next steps. The next achievable steps will be an evaluation by the room operators such as neurosurgeons and ward staff. From the evaluations received it will be possible to validate what is proposed in order to iterate the process by implementing what emerged to insure and validate the concept of the project.

Figure 6: Benefits achievable.