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A Challenge for Systemic Transformation towards Circular Healthcare Economy: Single-Use or Not?

Döngüsel Sağlık Hizmeti Ekonomisine Yönelik Sistemik Dönüşüm İçin Bir Zorluk: Tek-Kullanımlık mı, Değil mi?

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ABSTRACT

The study aims to discuss the challenge of systemic transformation of healthcare economy in the context of disinfection and sterilization (DAS) process. The database of the Web of Science (WoS) has been used to obtain data. In R environment, a variety of analyzes have been conducted through the biblioshiny. Following the descriptive findings, trend words, trend word weights and related visuals have been obtained. Multiple correspondence analysis was used to evaluate the development course of trending words by year, and the ggplot2 package has been used to visualization. An attempt has been made to draw attention to the difficulty of the systemic transformation of the healthcare economy by supporting the circular approach concepts featured in the publications with knowledge and experience from the field. The number of publications and citations in the field has shown an increasing trend. Prominent studies have been conducted in the areas of infection control, dialysis, anesthesia, and analgesia. Trend words have shown that life cycle assessment, reuse, sterilization, reprocessing, etc. concepts have a high level of centricity and concentration. Similarly, multiple correspondence analysis findings have shown that a heavy reliance has been placed on DAS processes in recent studies. The results clearly show that the systemic transformation from a linear healthcare economy to a circular one will create challenges for hospital administrations. It is therefore assessed that a hybrid approach to the continued use of disposable products instead of a purely circular approach will be beneficial to the sustainability of healthcare.

Anahtar Kelimeler: Healthcare, Linear Economy, Circular Economy, Single-Use, Reuse

ÖZ

Çalışma sağlık hizmeti ekonomisinin sistemik dönüşümünün zorluğunu DAS süreci bağlamında değerlendirmeyi amaçlamıştır. Veri elde etmede Web of Science (WoS) veri tabanı kullanılmıştır. R ortamında biblioshiny aracılığıyla çeşitli analizler yürütülmüştür. Tanımlayıcı bulgular sunulduktan sonra trend kelime, trend kelime ağırlıkları ve bunlara ilişkin görseller elde edilmiştir. Trend kelimelerin yıllara göre gelişim seyrinin değerlendirilmesinde çoklu uyum analizi, görselleştirmede ise ggplot2 paketi kullanılmıştır. Yayınlarda öne çıkan döngüsel yaklaşım kavramları sahadan bilgi ve deneyimlerle desteklenerek sağlık hizmeti ekonomisinin sistemik dönüşümünün zorluğuna dikkat çekilmeye çalışılmıştır. Alandaki yayın ve atıf sayısı artış trendi göstermiştir. Öne çıkan çalışmalar enfeksiyon kontrolü, diyaliz, anestezi ve analjezi alanından gelmektedir. Trend kelimeler; ömür devri değerlendirmesi, yeniden kullanım, sterilizasyon, yeniden işleme vb. kavramların yüksek merkezilik ve yoğunluk düzeyine sahip olduğunu göstermiştir. Benzer biçimde çoklu uyum analizi bulguları yakın tarihli çalışmalarda DAS süreçlerine fazlaca vurgu yapıldığını ortaya koymuştur. Bulgular doğrusal sağlık hizmeti ekonomisinden döngüsel sağlık hizmeti ekonomisine yönelik sistemik dönüşümün hastane yönetimleri üzerinde zorluklar yaratacağını açık bir biçimde göstermektedir. Dolayısıyla sağlık hizmetinin hastane düzeyinde sürdürülebilirliği için salt döngüsel yaklaşım yerine tek-kullanımlık malzeme kullanımına devam edildiği hibrit bir yaklaşımın faydalı olacağı değerlendirilmektedir.

Keywords: Sağlık Hizmeti, Doğrusal Ekonomi, Döngüsel Ekonomi, Tek-Kullanım, Yeniden Kullanım

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INTRODUCTION

The past three decades of experience in the healthcare industry have shown that the economic approach adopted has had significant cost implications. As a result of the economic approach adopted, the substantial part of the cost is due to the medical products used in the provision of services.[1-2] Studies show that the product costs of service delivery are a significant burden on the healthcare system.[3] Moreover, the increase in the market for medical equipment in 2019 to USD 456.9 billion, which increased by 4.4% compared to 2015, shows the penetration power of this market in health systems. Manufactured and marketed as disposable or circular by manufacturers, these products are widely used in service delivery, in particular in surgeries. Disposable products are managed within the framework of a number of standards after they have been used in the delivery of services. This situation has a significant impact on hospital resource utilization, processing costs, overpayment costs for excess waste, etc., which are constantly increasing healthcare costs. The intensity of use of disposable products varies from country to country.[1] The decrease in the likelihood of transmission of infectious diseases with the use of these products is seen as a clinical benefit.[3] Reprocessing of these products is reported to be unsuitable for sterilization and the possibility of increased infections poses a risk to patient safety.[4] In addition to clinical outcomes and healthcare costs, this situation contributes to social costs that lead to environmental destruction and affect community health in a variety of ways.[5] Although medical products produced by manufacturers with a circular approach are relatively expensive, their circular use in the service delivery process, preventing potential supply problems, minimizing environmental destruction, etc., are already used in the healthcare system. Studies in the literature indicate the need for a systemic transformation of the health system from the use of disposable products to the use of circular products.[2] Although the importance of using circular products has been noted in these studies due to the health and environmental benefits it will bring in the delivery of services, there remains uncertainty in the literature as to which approach is cost-effective in hospitals. Marshall, Dagaonkar, Yeow, Peters, Tan, Abisheganaden and Verma (2017) and Lilja, Julia and Lars (2017) studies have reported that disposable bronchoscopes save process costs and help reduce the risk of infection. Similarly, another study Mouritsen, Ehlers, Kovaleva and Ahmad (2020) demonstrated that cross-infection caused by the reuse of disposable bronchoscopes and the single-used use of these products, due to treatment costs, dominates reuse in the context of cost-effectiveness. Critical, semi-critical and non-critical products in the hospital are critical to continuity and quality in service delivery. It is extremely important that critical products, especially used extensively in operations, are ready for sterile use at any time. In this process, where the disinfection and sterilization unit of the hospital plays a vital role, the sustainability of circular products use can be made possible by the vertical organization approach. However, as Coase (1937) and Williamson (1975) point out, vertical organization is overpriced. The transaction costs are incurred when a work that is done within the market as per usual is done within the organization, the decision-makers need to make a choice at this point. Will the required product/service be delivered within the market environment or will it be produced within the hospital system through a vertical organization approach? Currently, products used in the provision of health services in Turkey are ready for reuse following DAS processes in central hospital sterilization units. Some products passed through these processes are disposable, and some are circular products. When it comes to the reuse of these products, the processing costs incurred by the hospital DAS units are significant. Each process carried out at each stage of the DAS process has a cost. Although it is difficult to measure the costs of the process in question, every process involves

costs from product separation to washing, packaging and sterilization. These kinds of cost pressures on the healthcare budget have increased the importance of economic assessment studies on alternative approaches, as Drummond, Sculpher, Claxton, Stoddart and Torrance (2015) pointed out. Although uncertainty remains as to whether DAS dominates the use of disposable products in the context of cost-effectiveness, recent studies have also shown that some disposable products dominate the circular approach in the context of cost-effectiveness.[6-7-8] In the study, the challenge of systemic transformation in the use of circular products, which are encouraged in the direction of a purely circular economy rather than a linear economy, was discussed at the micro level through the DAS process. It is believed that the study will provide an insight for the roles expected of stakeholders in a possible course of action to address the challenges that lie ahead in the process of systemic transformation in detail with real-life practices.

HEALTHCARE ECONOMY: LINEAR AND CIRCULAR PRACTICES

Conceptual frameworks related to the concept of linear economy are laid down by studies in the field of industrial ecology, and whether or not the economy is linear or not is characterized by the resulting material flows.[12] Consequently, the raw materials obtained in a linear economy are transformed into products, these products reach the end of their functional life by using them for a specific purpose in the economic system and are managed as waste without reuse.[13] In the 1970s, the concept of disposable products became widespread in parallel with developments in material science. These developments have added strength to efforts to produce complex medical products with low-cost plastics. Advances in surgery, the increase in minimally invasive surgery and the rapid increase in the production of highly complex and highly critical disposable products have also led to a rapid increase. Since the products developed during this period were designed in accordance with the DAS processes in the health system, they could be reused.[14] Today, the highly observed density of disposable products in the field of healthcare clearly shows that the concept of linear economics corresponds to a considerable extent in the field of healthcare. Most of the products used in the provision of healthcare services, particularly in surgical branches consist of disposable products. Surgical operations performed in cardiovascular, brain and general surgery branches are one of the major operations in which disposable products are widely used. Once these products are used for a specific purpose by service providers, the process is managed in accordance with the standards and procedures for waste management.[15] Products used in coronary bypass, mitral valve, and aortic valve operations, such as aspirator, electrocautery, scalpel, aortic valve, coronary scalpel and blue clips, are only some of the disposable products. Although a number of critical products used in major operations are disposable, they can be reused by surgeons due to cost pressures and products supply difficulties.[13] Since after being used in surgery, a disposable scissor used in cardiovascular surgery should be discarded, the surgeon may request that these scissors be sterilized and reused due to failures that may occur in the supply of surgical services. In many countries, including the United States and some European countries, it is known that disposable products are being reused for the delivery of health care.[1] Several studies in the literature have called attention to that products should be used with a circular approach rather than with a circular approach, but increased costs in the health system and pressures towards financial sustainability make it difficult to supply circular products and lead service providers to supply disposable products to a large extent. Disposable products, which are heat-sensitive, relatively cheap products in plastic structure, are supplied to use directly sterilized by the manufacturer and/or distributor companies; these products are low in cost, disposable and disposed of and are not environmentally friendly products. In addition to their complex structures, these products are non-

disassembled, electronic, durable, delicate, and sensitive to high temperatures. Products are used circularly in the circular healthcare economy, as opposed to the linear economy approach. Circular products are environmentally friendly products that can be easily disassembled to the smallest part and installed for reuse, easy to clean, resistant to appropriate DAS processes, do not lose their functionality in the washing and disinfection process and do not deteriorate and wear out after these processes, the sterilization process can be fully performed, the initial investment cost is high, but the DAS unit costs are low in reuse, helping to reduce the amount of waste. Cutting tools (scissors, castro, osteotomes, gouges, dermatome blades, pliers, bone holder), clamping tools (clamps, mosquito forceps, right angle forceps, vascular clamps, bulldog clamps, vascular clamps), holder/gripper tools (tissue forceps, bebcock forceps) retractors (automatic, abdominal, bladder), aspirator tips, sewing tools (needle holders, castro forceps), piercing and cutting motors (electric, air and charged), laparoscopic surgical tools (scissors, dissectors, clinches, graspers, bipolar cables, air hoses, reusable trochars and tips, aspirator tips, hooks, veress needles), monopolar, bipolar cords and ends and robotic surgical tools are the products used circularly. In the presence of these products, which can be reused through DAS processes, the circular healthcare economy emerges with its restorative and regenerative properties. In this approach, as products flow in a closed loop throughout the system, the amount of waste is minimized while maximizing the value of the product.[2] In these aspects, it is understood that the circular healthcare economy is closely linked to concepts such as sustainable development, resource efficiency, low carbon economy and green economy.[16] However, in some studies conducted in the field of anesthesia,[17] it has been reported that a lot of annual savings can be made for the healthcare budget by using circular products instead of disposable products, but reuse will generate more carbon emissions and more water needs to be consumed to produce these products.

METHOD

Detailed literature research has been carried out as part of the research and the conceptual framework in the field has been tried to be understood. Gray literature has been used in literature research, in addition to scientific publications. Upon understanding the conceptual framework, the researchers conducted a keyword selection study and decided what words should be used in the search for scientific publications. The search process was carried out in two stages in the Web of Science (WoS) database, which covers a numerous journal in the field of social sciences and is often used in bibliometric studies. In the first stage, all journal articles published in the period 1990-2021 were obtained using the keywords "health*" using the advanced search function. After that, all English articles published in the same period of years with the keywords “single-use”, “reuse” and “reusable” in the study title were obtained. In the second stage, the articles obtained in two different searches were combined and 151 articles published in the field of health were obtained. After the studies obtained have been downloaded to the computer environment, they have been transferred to the R environment[18] for various analyzes. In order to investigate whether there is duplication of data, studies with the same title were removed from the data using the filter function of the dplyr package presented by R. As a result of this process, it was understood that the number of publications obtained was 150 and that the analysis was carried out through these publications. As part of the bibliometrix package, the biblioshiny interface is used for analysis in the R environment.[19] Using RStudio, the bibliometrix package was activated and the biblioshiny function was provided for access to the interface. After the interface is opened, the publication data is transferred to this environment and prepared for analysis. Data analysis was carried out with the adoption of

a data discovery and visualization approach. Analytical findings on the development dynamics were presented after the basic descriptive findings of the publications were presented with box plots, scatter plots, intensity plots and box-scatter plots. The ggplot2 package offered by R is used for data discovery and visualization purposes. For this purpose, the results of publications have been obtained using the ggplot function. In addition, a multiple correspondence analysis of how words show an evolutionary structure relative to years has been investigated. The parameters required for multiple correspondence analysis are discussed in the context of the values presented by the biblioshiny. Although bibliometric methods are valuable tools for the discovery of the evolutionary structure of the field being studied, the adoption of only these tools in studies creates comprehension constraints. When the evolutionary structure is revealed, it becomes very important in which context the words which stand out are used. Therefore, a different approach was adopted in the study, and the study was supported by both theoretical and field experience, as well as bibliometric analysis. Following the revelation of the importance of trending words in the field studied, their importance in the provision of healthcare was evaluated in detail. Supporting the results of the bibliometric analysis with the field experience constitutes the strong aspect of the research.

RESULTS AND DISCUSSION

Descriptive results for publications are shown in Figure 1 and the results for publications with citations of 50 and above are shown in Table 1. It was therefore understood that the number of publications and citations showed an increasing trend towards the present day. Citation density and box-scatter plots show that very few studies have a large share of the total number of citations. The descriptive findings of the studies are summarized in Table 1. Considering Figure 1 and Table 1, when examining the findings of the citations, it is understood that the most cited studies are the first field studies from sources related to infection management, dialysis services and anesthesia and analgesia, respectively. According to the findings, it is understood that publications with high levels of centrality and intensity in the field are published in journals related to infection control. The fact that the publication in the field of nephrology is included in this group shows that dialysis services require intensive resource use.

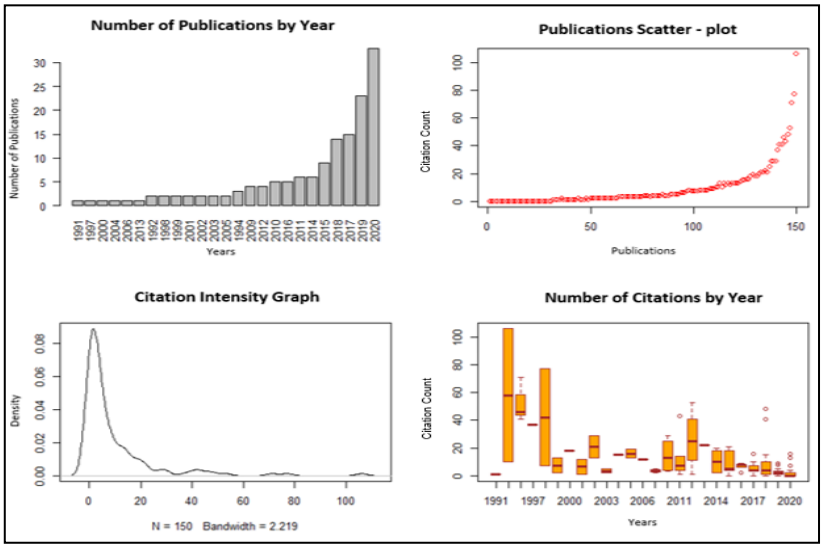

Figure 1. Descriptive Findings Related To Publications

Table 1. Descriptive Findings Related To Publications (Number of Citations >= 50)

Researchers	Publications	Year	Number of Citations	Journal Name	WoS Category
Brooks, SE; Veal, RO; Kramer, M; Dore, L; Schupf, N; Adachi, M	Reduction in the Incidence of Clostridium-Difficile-Associated Diarrhea in An Acute Care Hospital and A Skilled Nursing Facility Following Replacement of Electronic Thermometers with Single-Use Disposables	1992	106	Infection Control and Hospital Epidemiology	Public, Environmental & Occupational Health; Infectious Diseases
Collins, AJ; Ma, JZ; Constantini, EG; Everson, SE	Dialysis unit and patient characteristics associated with reuse practices and mortality: 1989-1993	1998	77	Journal of The American Society of Nephrology	Urology & Nephrology
Chen, SK; Vesley, D; Brosseau, LM; Vincent, JH	Evaluation of Single-Use Masks and Respirators for Protection of Health-Care Workers Against Mycobacterial Aerosols	1994	71	American Journal of Infection Control	Public, Environmental & Occupational Health; Infectious Diseases
Eckelman, M; Mosher, M; Gonzalez, A; Sherman, J	Comparative Life Cycle Assessment of Disposable and Reusable Laryngeal Mask Airways	2012	53	Anesthesia and Analgesia	Anesthesiology

Concepts such as sterilization, reprocessing and reuse have emerged as trend words in recent studies, and the results of multiple correspondence analysis related to this are shown in Figure 2. The reuse of disposable products leads hospital managements to adopt either one of two different approaches to DAS processes or a hybrid method consisting of two approaches. When the hospital management decides to reuse these products within the hospital, the vertical organization approach is at issue. This may increase the processing costs incurred by hospital management. A large number of cost items can be mentioned, such as capital costs, operating costs, and technical maintenance and repair costs, labor costs caused by the technology used in DAS processes. Hospital management can outsource these services by transferring them to a company in the market[20] by not choosing the vertical organization approach, or by using a semi-vertical organization approach, it can sterilize some critical products within the hospital and transfer the sterilization of some non-critical products to the contractor company. There is not enough evidence, however, as to which disposable products, intuitive decisions that the method of sterilization of such products is more cost-effective than the delivery of products, and efforts to reduce the amount of waste lead to the choice of reuse of such products. Some disposable products are reused after DAS processes in the health institutions with high numbers of bed capacity,[20-21] especially in most surgical operations,[22] but growing concern about the adverse effects of the health care industry on the ecological environment has revealed the importance of the need to evaluate the life cycle of the products used.[5] At the same time, the findings of the study indicate that products should be reused in the healthcare system. In these studies, the words sterilization, life-cycle evaluation and reuse refer to the DAS processes evaluated in the context of the vertical organization approach in the field of health care. In the following part of the study, the DAS process, which produces compelling re-use effects, was discussed in depth and an attempt was made to contribute to a critical issue that is often mentioned in field-based knowledge and experience studies. For this purpose, it was attempted to draw attention to various types of difficulties that will be created by the intensity of reuse of disposable products in the system in the circular approach by systematically conveying the DAS process

in 3 stages: washing, packaging and sterilization.

A. Vertical organization approach is costly: Challenge of disinfection and sterilization

The vertical organization approach is discussed in the literature within the framework of the transaction cost approach. The understanding of the classical economics, management, and organizational structures of classical theory, combining the concepts of rationality transaction cost approach, makes a comparison between the transaction costs incurred by an organization in its own structure and the transaction costs incurred when providing a product and/or service from providers outside the organization, and seeks a balance for organization.[9-10-23] In the healthcare sector, the question of whether hospitals should perform DAS on-site operations or provide these services from a provider shows that the hospital DAS process results in a vertical transaction cost induced by the organization. When the word weights shown in Figure 2 are analyzed, it is clear that this discussion is reflected in the publications. The fact that words such as disposable, reusable, and reusable instruments have a high level of centrality and density reveals the importance of the approach needed for the use of products in the field of health.

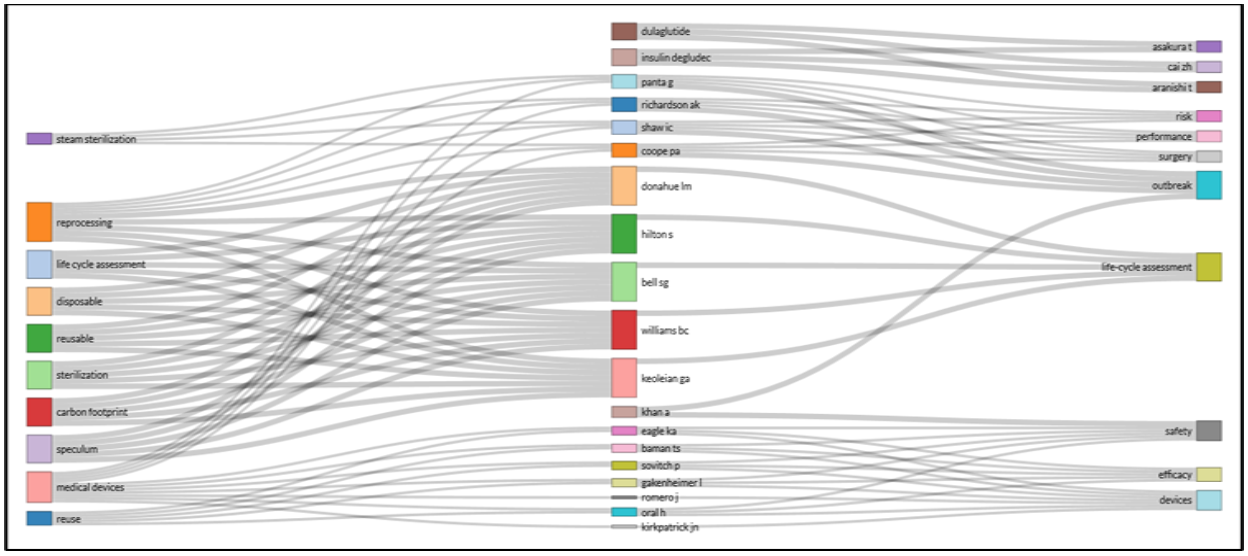

Figure 2. Trending Words

When hospital management adopts a vertical organizational approach, circular processes are activated to ensure the reusability of resources within the system. The hospital sterilization unit plays the most basic role in this circular process. Depending on the operating room, the sterilization unit plays a vital role in providing health care without disruption, but DAS processes are not simple and inexpensive. It is very challenging, to plan, organize, and control these services within the hospital system and provide feedback with high potential to enhance the system with the feedback mechanism. For this reason, from a managerial point of view, the management of these services, as well as the health service, which is the main duty creates different kinds of challenges. The washing machines, autoclaves, hydrogen peroxide, training, and orientation of employees for the effective use of technologies such as ethylene oxide, technical maintenance and repair of the technology used, the chemicals and biologics that need to be used further depending on the updated standards and the costs created by all products used for DAS purposes create important barriers to reuse of disposable products.

The word trend by year (Figure 1) and the high centrality of the word sterilization in the trend word network (Figure 3) indicate that sterilization is a critical step in the DAS process. On the other hand, in order to evaluate the reuse and life cycle, the cost of each process performed in sterilization must be calculated. Sterilization is therefore closely related to the concepts that stand out within the network, such as reuse, reprocessing, sustainability and life cycle assessment. Although the word sterilization is mainly featured in publications, this word covers not only sterilization, which is the third stage of the DAS process, but the entire phase of washing, packaging, and sterilization. For this reason, the sterilization process was conveyed in 3 stages: washing, packaging and sterilization. Each of these stages is systematically conveyed in order to draw attention to the possible compelling effects on hospital administrations due to the processing costs that they will create at each phase.

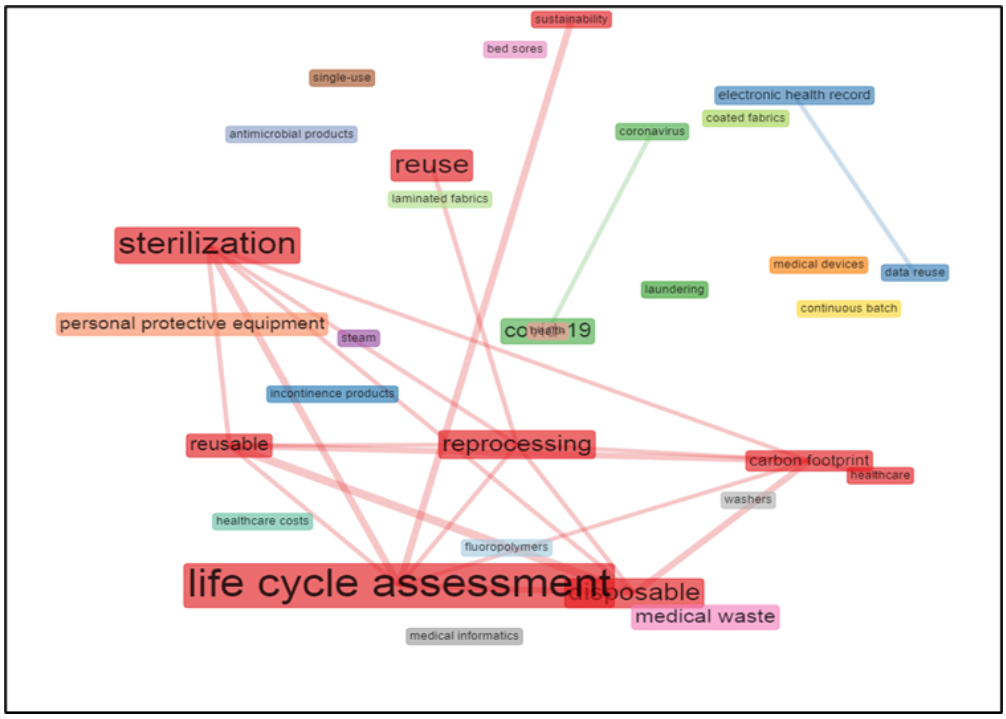

Figure 3. Trending Word Network

The trend words and weights presented in Figure 4 draw attention to the importance of the DAS process, but these studies did not take into account the cost increases created by vertical organization due to the increased use of circular products. Apart from the concept of life cycle evaluation in publications, the lack of a concept(s) that draws attention to the costs that products will create in the context of vertical organization clearly demonstrates this situation.

Figure 4. Trending Word Weights

Disinfection

All products used in patient interventions are either disposed of in medical waste by following the appropriate procedure or sent within a short period of time to the sterilization unit for circular use. The time between the end of the product use and the washing process is essential because surgical instruments remain for more than 20 minutes with blood and tissue residues, which can lead to corrosion that leads to the products' expected life shortening. Disposable and circular products delivered to the soiled area of the sterilization unit are divided into disposable and circular after being counted and recorded by the sterilization unit personnel. Examples of disposable (non-assembled) and circular products (assembled) used extensively in operations are presented in Figure 1 below to demonstrate the importance of the effectiveness of the DAS process. Both product groups are subjected to the same process of washing. For the effectiveness of sterilization, it is important to remove dirt, blood, protein substances, microorganisms, and other residues from notched and lumen instruments with the help of detergent/enzymatic cleaners in the washing products process. In the washing process, products are functionally separated, such as cutting tools, clamps, holder/gripper tools, retractors, suction tools, sewing tools. After disassembling these separated tools, each of them is placed in a separate washing rack and the rough dirt of these tools is removed with water. For effective washing of surgical instruments such as aspirator tips, veress needle, air hose, reusable trochars, laparoscopic lumens cleaning is provided up to the end points with the help of a brush. After these products are also classified according to their material structure, type, heat resistance and size, the washing process is carried out by automatic washing machine, ultrasonic washing, or manual way. The mechanical process, heat, time, and chemicals occupy an important place in the automatic machine's washing process. It is important that the quality and temperature of the water used in the washing process, chemical solutions are non-corrosive, non-foaming, easy to rinse and environmentally friendly, the ability to quickly dissolve and disperse dirt, non-toxic, long shelf life and have properties such as being effective in all kinds of organic dirt. After washing and rinsing, high temperature water should be sprayed for a certain period of time. According to the intended use of the products semi-critical instruments (flexible endoscopes, nasal cannulas, airway, aspiration probes in contact with mucous membranes) at 80 °C for 1 minute, the critical equipment (surgical

instruments, cardiac and urinary catheters and implants entering sterile tissue and vascular system) at 90 °C for 5 minutes process implemented. In addition, internal and external cleaning of the machine with disinfectant is carried out every day, control of its filters, and control of the holes of the spray arms, cleaning of the racks placed in the device. At the end of the applied washing cycle, the load, washing chamber and inner surfaces of the washing machine are evaluated by the dirt residue washing efficiency test (Dirt test). In addition, after this procedure, protein residue testing is performed to ensure that proteins are removed from surgical instruments. The machines are not overloaded by the operator for each process in which the automatic washing cycle is used, the correct placement of products placed in the basket, the opening of locks on articulated and locked products will contribute to the effective management of the sterilization phase. Ultrasonic washing is the process of cleaning to decontaminate the tools such as lumen and difficult to wash, particle, complex structure of tools, products that are not resistant to high temperature with the addition of neutral or alkaline, but non-foaming detergent to the water, based on the vibration of sound waves and the shaking of water at a certain speed by forming micro bubbles, from dirt, blood, and residual substances. After the device runs for 5-10 minutes, the instruments are rinsed with deionized or demineralized water and dried. The characteristics of detergent and enzymatic products play an important role in this process. If enzymatic solution is to be used, it is noted that the temperature is no more than 45 °C. The type of washing solution is chosen according to the daily or pollution status. At each change, cleaning of the device is carried out with disinfectant. In cases where the machines are malfunctioning or do not exist, manual washing is carried out. The instruments such as precision micro instruments, large and complex instruments by volume, long and thin lumen instruments, laparoscopic instruments are disassembled to the smallest detail, after pressurized water and air are passed through the cannulas, the joints of the instruments are thoroughly opened, and coarse dirt is cleaned under water and placed in washing baskets, taking care not to overfill. The instruments are soaked in a washing solution (detergent, disinfectant or enzymatic) below 40 °C and left for a few minutes. Each instrument is then cleaned with a soft-tip brush, sponge or cloth, or lumen tools with a surface brush of the appropriate size and diameter. After cleaning, the instruments are rinsed under water, dried with a cloth, or compressed air. Electric/battery-powered devices that cannot be immersed in water are wiped and rinsed with a cloth soaked in solution and then dried. Especially attention is paid to the cleaning of products with high cost such as optics, telescopes, light sources, cables, cameras, and instruments used in robotic surgical operations without breaking and in a precise manner.

Packaging

The second phase in the sterilization process is the packaging phase. This phase is the process by controlling the cleaning of the products again, ensuring the packaging process by placing them in a certain order in the set and container, as well as deciding how to sterilize the products that need to be wrapped separately, the final packaging process is carried out in accordance with this decision. First of all, packaging must be done in a clean area. It is expected that the personnel responsible for the packaging process will continue this process by using protective equipment (mask, bone, gloves, arm-cover, apron, etc.). It is important that the packaging environment is adequately illuminated and that the ventilation, ambient temperature and humidity are well adjusted. In terms of the integrity, controlling damage and functionality of the decontaminated products is critical steps for the packaging process: in the terms of completeness and operability if the instrument is a medical device; lubricity of the instruments such as scissors, needle holders and clamps controlling properly opens and closes, and removal of stains and rust with solvents, if any; and place them in a set or container in a certain order by counting them in an appropriate format due to the list. In this

process, the weight of the products placed in the basket is distributed evenly, and if there are pointed and sharp instruments among them, a protector is attached to their tips. Ensure that these preservatives allow vapor penetration between the instruments, otherwise it is not possible to talk about an optimal sterilization process. If it is determined that there is a missing instrument during the packaging process, the details of the missing instrument are recorded by providing an interview with the relevant personnel using the set in the operating room. After checking the instruments, a disposable clean cover is laid in the set or container. This cover prevents the movement and damage of the instruments, as well as contributes to the dispersion of the condensed steam formed in the autoclave and the drying process is more effective. After this process, a chemical indicator is attached by placing a delivery form containing the name of the person who made the packaging in the set, the name of the set, the date, and the name of the missing product, if any. The most significant indicator that indicates if the set is sterile is this attached indicator. If the indicator specified in the set is not available, this set is not considered non-sterile and is not used when it is opened. The lid of the container in which the product is placed is checked during the packing process and the containers are maintained, filter change and replacement at certain intervals. The products made ready for autoclave after the container is closed, the lock is installed, and the label is attached. If the instruments are placed in the set, the opening and deterioration of the integrity of the set is prevented by inserting process tape onto the textile covers or after wrapping them in an outsourced disposable packaging product the envelope or rectangle method. At the same time, the color change of the process tape is an indicator for the sterilization process. Other products to be packed separately outside the set are separated in precision according to its structure and length, heat resistance, containing of cellulose, cotton weaving. Lumen products that do not contain cellulose or cotton weaving and are sensitive to heat, and some robotic products with a length of less than 1 meter are separated to be sterilized in a hydrogen peroxide device. For these instruments, disposable polypropylene/polyethylene roll packing product and tape are used. For an ethylene oxide device, heat-sensitive instruments with a length of more than 1 meter are packaged among the lumen instruments. Implants, respiratory products, cotton, and absorbent products are not suitable for sterilization with ethylene oxide. Retractors, bowls, curettes, and metal instruments are all separated for autoclave sterilization. For ethylene oxide or pressure steam sterilization, disposable sterilization bags with a class 1 chemical indicator are used, consisting of a film layer on one side and paper on the other a chemical indicator is placed in each package content. If the products packaged for sterilization with hydrogen peroxide are incorrectly separated or incorrectly packaged, the hydrogen peroxide sterilizer gives an error. As a result, operations are disrupted, and repackaging the instrument will lead to paper waste and an increased cost burden.

Sterilization

The sterilization phase, which is perhaps the most critical phase of the DAS process, uses methods such as high-temperature steam sterilization, low-temperature ethylene oxide, formaldehyde, hydrogen peroxide, ozone, ozone + hydrogen peroxide, chlorine dioxide, peracetic acid vaporization and nitrogen dioxide.[25] The sterilization methods used may vary depending on the hospital's capacity, size and needs. In the study, steam autoclaving, ethylene oxide and hydrogen peroxide were presented to be the most commonly used methods in the DAS process.

Autoclave

In terms of volume, there are different steam sterilizers. Steam sterilizers work as a displacement and air evacuation system (pre-vacuum and steam injection). It is suitable for the use of products such as textiles, containers, roller bags, disposable wrapping products capable of protecting vapor permeability and sterility. Failure to comply

with these standards, as indicated in the sterilization process, leads to a decrease in the efficiency of sterilization, which may lead to situations requiring a repeat of this process. The package sizes must be appropriate for sterilization. The objective here is to ensure that saturated steam can easily reach every region of each package or product contained in the load. A certain amount of space is left between each package to ensure that the Steam reaches each region. After the packages and sets made in the clean area are moved to the sterile area with the help of the loading trolley (these trolleys used in transportation are decontaminated after each use), these products are separated according to the sterilizer to be sterilized. After completion of the loading process, an appropriate sterilization program is selected based on the properties of the product to be sterilized. Each cycle is controlled by chemical and biological indicators during sterilization. Vacuum leakage test and Bowie-Dick test are used to check the effectiveness of sterilization and to test whether saturated steam penetrates the load to be sterilized quickly and properly and the ability of the sterilizer to drain the air in the cabin and prevent re-entry by performing every day as the first cycle of the day. Chemical indicators, biological indicators, electronic systems, and device outputs are considered for the control of the sterilization process. During the process, the chemical indicator is first looked at. It is examined whether there is a color change in the indicator, the absence of color change indicates a problem in the process. Try to determine why the problem is caused by thoroughly reviewing the location and position of the indicator in the load. In such a case where the problem cannot be fixed, the product is considered non-sterile and the load is sterilized in another machine. Biological indicators critical to the control of the sterilization process are products containing spores of microorganisms. It is important that the biological indicators are correctly located in the load and that the indicators are placed in the incubator. In the event that the biological indicator delivers a positive result, the products are repackaged and loaded into another device and the sterilization process is completed. The electronic test system (ETS) is a data system that reveals the performance of sterilization in the sterilization process. This system, which provides data flow for both load and in-pack sterilization by recording the heat and pressure sensor in pressurized steam sterilizers during the cycle, provides information as to whether the necessary operations have taken place during the sterilization process with the output of the device it produces. In these monitoring processes, any value is missing, or incorrect results cause the process to be restarted, waste products used, workload and cost increase.

Ethylene Oxide

It is sterilization method used for products with high temperature sensibility and synthetic, fiber optic, PVC products with no lumen length and diameter limitation. Ethylene oxide sterilization provides advantages in aspects such as easy to operation and monitoring, high penetration power, high microbicidal effect.[24-25-26] But it has disadvantages in aspects such as being a first-class carcinogen and being able to leave toxic residues, long sterilization, and ventilation time. In order for this method to be applied, it is an expensive method that requires various structures and systems such as separate room with ventilation system, necessary infrastructure, alarm, and gas leak alarm systems. When the packaged products are sterilized in an ethylene oxide sterilizer, biologic and chemical indicators are placed in the sterilizer for each cycle. Upon completion of the cycle, a documentation label containing the name of the personnel, the number of the machine, the date of sterilization of the products and the expiry date shall be affixed to the products. The products are ventilated for 48 hours at the end of the process.

Hydrogen Peroxide

It is used as a sterilization method of heat-sensitive, sensitive surgical instruments, electronic instruments, and robotic products. Special packaging product and tape that does not contain cellulose and cotton weaving are

used in sterilization and packaging with hydrogen peroxide. It is a safe, non-toxic residue-free, fast, easy to install and use, can be disassembled, reliable sterilization method for personnel, patients, and the environment.[24-25-26] The content of the load, the length and diameter of the product, the occupancy rate of the load are important. The device for sterilization is sensitive to moisture and cellulose. During the hydrogen peroxide method, each package is recorded in the file before loading, and the label is attached to each product with the information such as the name of the personnel loading the product, number of cycles, machine number, the date when the product was sterilized, and the expiration date. If the loaded product is humid or is not suitable for the sterilizer, or if the device is overloaded, the device will fail during the cycle. In such a case, the product will be re-dried and packaged. Biological and chemical indicators are used for each cycle. The output of the device and the results of the biological-chemical indicator are recorded in the file at the end of the cycle. If there is a positive biological indicator, the hydrogen peroxide device will run three empty cycles after maintenance and repair of the device and the incubator is achieved. Biological indicator planting is carried out to control the sterilization performance of each cycle. As a result of the performance test, if the biological indicators show that effective sterilization has not been carried out, the products will be repackaged, loaded into the sterilizer and the cycle will start again.

Over the last three decades, the use of disposable products has increased dramatically due to increasing applications in medicine, particularly in minimally invasive surgery.[1] In this respect, the health care industry is taking a stand against us as a field dominated by linear economics practices.[2] The use of vascular clamps and ecartors in coronary bypass surgery, aortic valve surgery and mitral valve surgery, which are the primary major operations, also clearly shows that a circular approach is being adopted in the field of health, and some studies emphasize that circular economy practices contribute to the control and cost savings of hospital infections.[13] In this study, the difficulty of systemic transformation from a linear health care economy to a circular economy was discussed in the context of the micro-level DAS process. Overall, the findings suggest that a circular approach in the health care economy should be adopted. Concepts such as life cycle assessment, reuse, and sterilization have shown that products should be evaluated within the framework of a circular approach for reasons such as sustainability and carbon emissions, rather than a disposable product approach. However, the findings on the challenges and transaction costs of the circular approach in the context of the vertical organization approach are insufficient in these studies. As outlined in the study, the DAS process, which is considered as part of the vertical organization approach, is a very challenging and costly process, and each phase of the washing, packaging and sterilization process is managed within the framework of a number of standards. Given that DAS operates within the framework of these standards, compliance with these standards is critical to the effectiveness of the work performed. The use of products marketed by the relevant companies under the phrase disposable with a circular approach due to cost pressures indicates that quality standards are not met in essence. Depending on the structure of these products, the decontamination process cannot reach the extreme point of the product, as a result of which the blood and waste cannot be completely cleaned and even some of the products are not suitable for drying, although decontamination has been achieved, which poses a major problem for the DAS process. Failure to effectively sterilize these products poses a great risk to health care quality due to the risk of infection. Since instruments such as disposable ligasures, endo-gia, laparoscopic instruments, scissors, dissectors, trochars contain many joints and narrow lumens, optimal cleaning is not possible in these products. The multiplicity of indentations and folds in such products, and especially at the endpoints that come into contact with the patient, makes the cleaning of the products

almost impossible. In as much as possible, the success of the DAS process from a clinical safety perspective is made possible by removing all kinds of biological products from the product used in the patient's intervention.[27] But when DAS processes are performed for disposable products, there are 2 main risk factors, such as mechanical or chemical product damage due to repetitive process and insufficient sterilization.[13] Since products are exposed to different chemicals and processes, changes in these products, corrosion, wear, and mechanical deterioration of the end parts of the products may occur due to their plastic structure. In addition to damaging the physiological structure of the product, its functioning may deteriorate, resulting in a decrease in the efficiency of the product. However, the whole of the research questions within the framework of legal and ethical problems are; the loss of products during DAS process, not knowing whether decontamination and sterilization processes are performed effectively, how the products will be billed again, becoming impossible to follow up against possible problems that may arise when records are not kept. It is extremely important that applications made throughout the sterilization process are carried out by people who have been trained, have knowledge and experience in this regard. In addition to the measures that personnel will take with protective equipment before washing, the training and experience of these personnel provides protection against cutting and piercing tool injury and cross-infection. In addition, in the cases such as the absence of the name of the personnel, and the instruments, lack of knowledge about the use of the machines and their maintenance, the contents of the disinfectants and maintenance sprays to be used by the personnel, the injuries may be caused by cutting and piercing instruments, incomplete and incorrect counting of the surgical instruments, failure of the machines with an incorrect application, deterioration of the product structure, may cause irreversible product loss and shortening of the shelf life of the products. As an example, if a high temperature sensitive product is packed with a sterilization bag and loaded into a pressurized steam autoclave, deterioration in the integrity of the product can lead to irreversible product loss, such as melting. If this product is expensive, financial burdens may arise and, since the delivery of these products by hospital administration will take time, a shortage of in-hospital product supplies may be a major obstacle to service delivery. This can lead to failures in the sterilization process and to consequences such as a weakening of the process. In addition, mistakes made in cleaning circular products can lead to failures in other fields of health service delivery processes, especially surgical operations, and an increase in hospital infections which have become chronic in health systems in recent years. Any deterioration in the integrity of the instrument occurs, or if any deficiency could not be noticed in the operation of the patient in a critical condition such as coronary bypass surgery, the desired intervention could not be made and a similar product could not be found, stress and anxiety that may occur within the team may become unavoidable. In such a case, the return of a set that has opened and lost its sterility, even if it is sterile, to the sterilization unit can eventually lead to unexpected costs such as labor, products, electricity, water, time which leads to the hospital administration incurring extra costs for the vertical organization.

CONCLUSIONS

In the literature, it is pointed out that the reuse of disposable products with a circular approach is economically beneficial, and it is revealed that a systemic transformation is needed for this. In the light of the studies carried out on this issue, it is understood that the use of disposable products dominates the use of circular products due to the cost savings of the process and the contribution it makes to the control of hospital infections.[6] Because some non-critical disposable products are both easy to supply and cheap, it is thought that it would be more appropriate for hospital management to manage them as disposable. In

a system where such products are completely reused, it is estimated that the development of a sclerotic structure in DAS processes will be inevitable. This resulting situation causes administrative complexity, and problems and failures in DAS processes can lead to a dramatic cost increase. The findings, supported by knowledge and experience from the field, clearly demonstrate that the systemic transformation from a linear economy of healthcare to a circular economy of healthcare will create challenges for hospital administrations. Therefore, it is assessed that a hybrid approach in which the use of single-use products is continued, rather than an approach in which only the circular approach is adopted, will be useful for the sustainability of the health service at the hospital level. In this regard, it is considered that if a roadmap is developed, it will gain applicability and prevalence through a process that will be effective for stakeholders such as hospital administrations, doctors, manufacturers, health authorities, reimbursement institutions, quality organizations and regulatory agencies.

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