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BULLETIN OF MICRO AND NANOELECTROTEHNOLOGIES BMNE

Editorial

Revista BMNE își propune să publice numai articole originale, ne-publicate, ne-trimise la alte publicații, prezentate la conferințe și ne-publicate în volumele manifestărilor științifice, și care prezintă *doar rezultatele finale ale experimentelor din contractele de cercetare științifică* din inginerie electrică, micro și nano-electromecanică, sisteme harvesting, bionică, inginerie biomedicală și din celelalte domenii ale științelor inginerești (min. 8 pag.–max. 16 pag.).

Sunt acceptate articolele ale căror autori sunt: elevi de liceu, studenți, drd., dr., cercetători științifici, cadre didactice universitare care învață sau lucrează în licee, institute de cercetări, societăți comerciale, universități din țară și străinătate.

Articolele, publicate în două versiuni, pe hârtie și online, sunt identice. Accesul liber online asigură o mare vizibilitate articolelor.

Revista BMNE a fost fondată în anul **2010** (ISSN 2069-1505) care, an de an, publică 1-2 numere / an.

Revista are un *Colegiu Științific* format din profesori universitari și cercetători științifici din România și din străinătate — personalități recunoscute din domeniul științelor inginerești (în special, din inginerie electrică, micro și nanoelectromecanică, inginerie biomedicală și din celelalte domenii ale ingineriei).

Tematica revistei ***Bulletin of Micro and Nanoelectrotechnologies (BMNE)*** include studii de cercetare specifice privind:

- componente micro și nanoelectromecanice;
- micro și nanoactuatori, micromotoare și senzori;
- microsisteme harvesting;
- tehnologii convenționale și neconvenționale MEMS (sisteme microelectromecanice) și NEMS (sisteme nanoelectromecanice);
- studii teoretice și experimentale asupra câmpului electric, magnetic și electromagnetic;
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- noi materiale în MEMS și NEMS;
- preocupări în domeniul standardizării și fiabilității;
- analize economico-financiare și evoluțiile piețelor specifice MEMS și NEMS;
- bionică.

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Editorial

The BMNE Journal aims to publish only the articles that are original, un-published, un-submitted to other publications, presented at conferences and un-published in the proceedings of those scientific events, and that present only *the final results of experiments included in the scientific research contracts* in the fields of electrical engineering, micro and nanoelectro-mechanics, harvesting systems, bionics, biomedical engineering and in other fields of the engineering sciences (min. 8 pages-max. 16 pages).

There are accepted the articles, whose authors are high-school students, college students, PhD students, PhD, scientific researchers, university teaching staff beneath other co-authors, and who learn or work in high-schools, research institutes, commercial companies, universities from the country and abroad.

The articles, published in two versions printed and online, are identical. The online open access ensures a high visibility of the articles.

The BMNE Journal was founded in **2010** (ISSN 2069-1505) that publishes, yearly, 1-2 issues / year.

The *Scientific Board* includes university professors and researchers from Romania and abroad — well-known personalities in the field of engineering sciences (especially, in electrical engineering, micro and nanoelectromechanics, biomedical engineering and other fields of engineering).

Topics area of the ***Bulletin of Micro and Nanoelectrotechnologies (BMNE)*** journal includes the specific research studies on:

- micro and nanoelectromechanical components;
- micro and nanoactuators, micromotors and sensors;
- harvesting microsystems;
- conventional and nonconventional MEMS (microelectro-mechanical systems) and NEMS (nanoelectromechanical systems);
- theoretical and experimental studies on electric, magnetic and electromagnetic fields;
- design proceedings and algorithms of MEMS and NEMS components;
- applications of MEMS and NEMS in biology and in biomedical field;
- new materials in MEMS and NEMS;
- standardization and reliability preoccupations;
- economic and financial analysis and evolutions of MEMS and NEMS specific markets;
- bionics.

The authors who published their articles in the BMNE Journal are from the country, from prestigious high schools and universities, and from abroad: Poland, Italy, United Kingdom of Great Britain and Northern Ireland, etc.

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Incorporating Immersive Learning in the Professional Training of Medical Bioengineers using Virtual Reality

BLĂNARU Maria-Monica [1], GRIGORE Diana-Elena *[1]

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Abstract

The use of virtual reality (VR) in the academic and professional training of the medical bioengineer can bring many benefits, contributing to the development of the skills needed in this field. VR provides an immersive and realistic experience, allowing users to interact with complex simulations, medical scenarios and virtual medical equipment without the associated risks of real practice. The main problem that such a learning system can solve is that of generating real experiences related to the future job, but also the in-depth understanding of some problems from real practice through the virtual environment. VR provides an effective way for medical bioengineers to maintain and update their knowledge and skills throughout their careers, allowing them to stay abreast of the latest technologies and advances in the field. Medical bioengineers work with a significant amount of medical data, such as medical images and patient data. Through VR, they can view and manipulate this data three-dimensionally and interactively, making it easier to understand and analyse it. The purpose of this paper was to create, with the help of specialized software, a virtual reality platform designed to provide training to the students of the Faculty of Medical Bioengineering, and not only, by offering them a detailed simulation of a hospital ward with related medical equipment.

Keywords: education, medical bioengineering, clinical immersion, interprofessional communication, simulation, virtual reality

How to cite this article:
BLĂNARU M.-M., GRIGORE D.E., "Incorporating Immersive Learning in the Professional Training of Medical Bioengineers using Virtual Reality", in *Bulletin of Micro and Nanoelectrotechnologies (BMNE)*, 2024, vol. 14, no. 1, pp. 05-06, ISSN 2069-1505.

1. Introduction

Virtual Reality (VR) is a technology that allows users to experience and interact in environments and situations that are digitally simulated. It involves the use of special equipment, such as virtual reality goggles, which transport users into a computer simulated world. Through VR equipment, users can feel that they are present and interacting in a computer-generated environment. VR technology mimics visual, auditory and sometimes even tactile sensations, allowing users to virtually feel like they are in the middle of a virtual world [1, 2]. Virtual reality has been increasingly integrated into medical and bioengineering education to enhance the learning experience, improve retention of knowledge, and provide a more immersive and interactive way of teaching complex concepts. VR can be used to teach students how to design medical devices and equipment as well as how to use them. They can build and practically test prototypes, which can be a valuable tool in biomedical engineering education. This paper presents a virtual reality platform with which different technical scenarios can be designed to provide training to medical bioengineers, providing them with a detailed simulation of a hospital ward. The purpose of this platform is to provide medical bioengineers with a realistic experience in a virtual hospital environment, focusing on the use of various VR accessories to be able to perform certain tasks related to patient monitoring [3].

II. Material and method

Virtual reality (VR) platforms are software and hardware ecosystems that enable users to experience immersive, computer-generated environments. These platforms provide the necessary tools and technologies to create, interact with, and enjoy virtual reality experiences [4]. Our VR platform is created in Unity Hub, with a focus on realistic details of a hospital ward, including medical

equipment, furniture and appropriate lighting (Figure 1). Unity provides a robust platform for developing VR content that can run on various VR headsets and platforms.

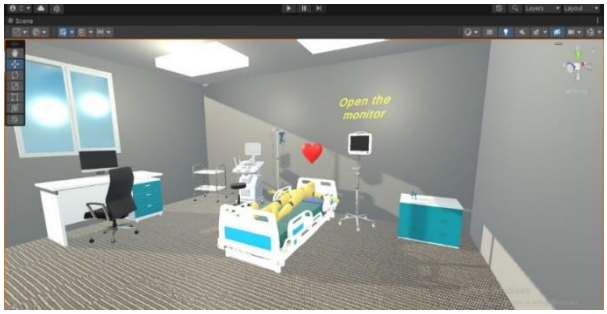

Figure 1. Hospital ward interface created in Unity

The VR interface allows medical bioengineers to interact with the environment, giving them the ability to turn patient monitors on and off and interpret physiological data, simulating real hospital situations. The medical bioengineer is responsible for the operations of the patient monitors, including turning them on and off according to the condition of the simulated patient. During training, the medical bioengineer is trained to interpret the simulated heart data and react appropriately, thus giving him/her hands-on experience in managing medical equipment (Figure 2).

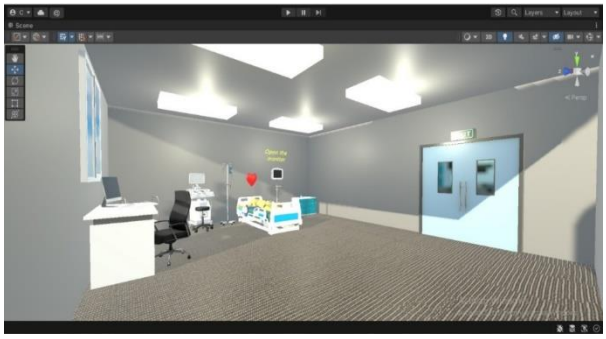

Figure 2. Different angle of the hospital ward created in Unity

The virtual reality experience helps prepare medical bioengineers for real situations, giving them the opportunity to learn and make mistakes without consequences on real patients. This approach provides the opportunity to practice and develop critical skills, preparing medical bioengineers and healthcare professionals for the complex demands of the medical environment.

III. Results and discussions

The created application provides components and systems for managing VR interactions, including hand tracking, manipulation of various medical devices in a medical ward. These tools are essential for creating immersive and interactive VR experiences. In the future, we want to expand the platform, offering the possibility of training medical bioengineers to perform maintenance and service of medical equipment in the virtual hospital ward. We also want students to have the opportunity to examine each component of a medical device in detail along with its specifications. Virtual education platforms can provide various assessment methods, including quizzes, assignments, and exams. Automated grading and instant feedback help students track their progress and make necessary improvements.

IV. Conclusions

The virtual reality system for personal training of medical bioengineers is an innovative and effective solution for developing knowledge and skills in bioengineering. Through full immersion in complex medical scenarios and advanced simulations, users can gain valuable hands-on experience and learn in a safe and interactive way. VR systems can track the progress of individual students and adapt the learning experience to their needs, providing additional support or challenges as required. With a wide range of benefits and facilities, this system contributes to the development of a more trained and competent medical and bioengineering workforce. While VR holds significant promise in medical bioengineering education, there are challenges, including the cost of equipment, content development and ensuring that the technology is seamlessly integrated into the curriculum.

IV. Bibliographic References

[1] Wilkerson M, Maldonado V, Sivaraman S, Rao RR, Elsaadany M, Incorporating immersive learning into biomedical engineering laboratories using virtual reality, J Biol Eng. 2022 Aug 8;16(1):20. doi: 10.1186/s13036-022-00300-0.PMID: 3594162.

[2] Singh A, Ferry D, Mills S, Improving Biomedical Engineering Education Through Continuity in Adaptive, Experiential, and Interdisciplinary Learning Environments., J Biomech Eng. 2018 Aug 1;140(8):0810091-8. doi:10.1115/1.4040359.PMID: 30003258.

[3] Singh A, Ferry D, Balasubramanian S, Efficacy of Clinical Simulation-Based Training in Biomedical Engineering Education, J Biomech Eng. 2019 Dec 1;141(12):121011-121011-7. doi: 10.1115/1.4045343.PMID: 31660578.

[4] Taylor B, McLean G, Sim J, Immersive virtual reality for pre-registration computed tomography education of radiographers: A narrative review, J Med Radiat Sci. 2023 Jun;70(2):171-182. doi: 10.1002/jmrs.657. Epub 2023 Jan 19.PMID: 36657747.

[5] Bailenson, J., Experience on Demand: What Virtual Reality Is, How It Works, and What It Can Do, W. W. Norton & Company Publisher, 2018.

Authors' Biographies

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Transforming the Future of Medical Technology Management through Digitalization

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Abstract

In recent decades, the medical field has been profoundly influenced by technological and digital advancements, and efficient medical devices management has become essential to ensure the quality of healthcare. Medical devices must be safe for both patients and medical staff, adhering to multiple criteria, including ensuring electromagnetic compatibility. In this context, biomedical engineers play a crucial role in the proper medical devices maintenance, ensuring they operate optimally and are available to patients at all times. The digitalization of the biomedical engineering field in healthcare facilities can streamline workflow, with all data accessible in real-time. This paper aims to provide an analysis of the needs of biomedical engineers in healthcare facilities. Based on these considerations and in compliance with current recommendations and regulations, the design of a computerized maintenance management system for medical devices has been developed. The purpose of this platform is to support biomedical engineers in their daily activities and contribute to a high-quality, modern, efficient, and sustainable healthcare system.

Keywords: medical devices, maintenance, management, digitization, biomedical engineer

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1. Introduction

The medical field has become increasingly reliant on technological innovations and the complex equipment associated with them, and the biomedical engineer serves as the bridge between modern medicine and engineering. They are responsible for the care of medical devices throughout their lifecycle within healthcare facilities, can train other healthcare professionals in the safe and efficient use of medical devices, participate in the assessment of medical technology, collaborate with procurement departments, and are an essential component of multidisciplinary risk management teams operating within healthcare units [1]. Medical device management is essential to ensure compliance with manufacturer specifications and to guarantee the safety of patients and users throughout the device's lifecycle [2]. In order to efficiently manage the costs associated with the maintenance of medical devices, every healthcare facility must develop and implement well-planned maintenance programs [3]. The World Health Organization maintains that a computerized maintenance management system (CMMS) is a tool that can enhance the overall medical device management within a healthcare facility. The information included in this system depends on the specific situation but invariably comprises the inventory of medical devices and typically includes data such as service history, preventive maintenance procedures, performance indicators, and cost-related information [4]. Internationally, there is an increase in the use of CMMS for medical devices. In the year 2022, there was a 9.6% increase in the countries that have adopted the use of such a system [5], [6].

II. Materials and methods

This paper aims to provide an analysis of the needs of biomedical engineers in healthcare facilities and to develop the design of a computerized maintenance management system for medical devices. We launched a survey to 9 biomedical engineers from different healthcare facilities in the

North-Eastern region of Romania, with questions about the current medical devices management process, the challenges they face, and the tasks that should be digitized. For the design of the web application interface for medical device management, we used Figma, and to build a minimum viable product, we employed JavaScript, Python, CSS, and HTML.

III. Results and discussions

After analysing the survey responses, we found that all the facilities use only paper records and Microsoft Excel sheets. The management and documentation tasks are affecting the time allocated to technical and engineering responsibilities in approximately 70% of the units. The main features that biomedical engineers wish to be digitized are presented in Figure 1.

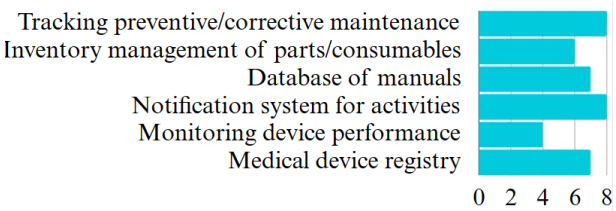

Figure 1. Main features for a CMMS based on biomedical engineer's responses

Following a review of current regulations and recommendations, the workflow presented in Figure 2 was developed. Through the system, biomedical engineers can track the maintenance history for all medical devices, monitor the stock of consumables and spare parts to prevent downtimes, view and update data in real-time, and eliminate the need for searching through archives, folders, or Excel files.

The system was designed as a web application to facilitate interaction on various platforms (Android, Windows, Linux, MAC, etc.). It can be accessed from any device (PC, smartphone, laptop, tablet) through a web browser (Edge, Safari, Chrome, Firefox, Opera etc.).

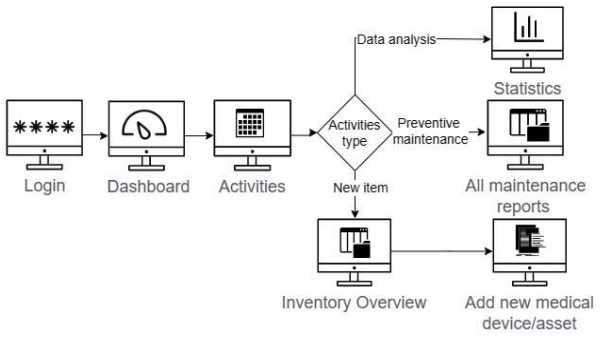

Figure 2. The main workflow of the designed CMMS

In the sections dedicated to inventory, the user can register a new medical device or item (spare parts, accessories, consumables). For a medical device, the mandatory information for the medical device registry must be completed: the name, type of medical device, manufacturer, country of origin, serial number, year of manufacture, inventory number, provenance document, date of commissioning, and electrical safety class.

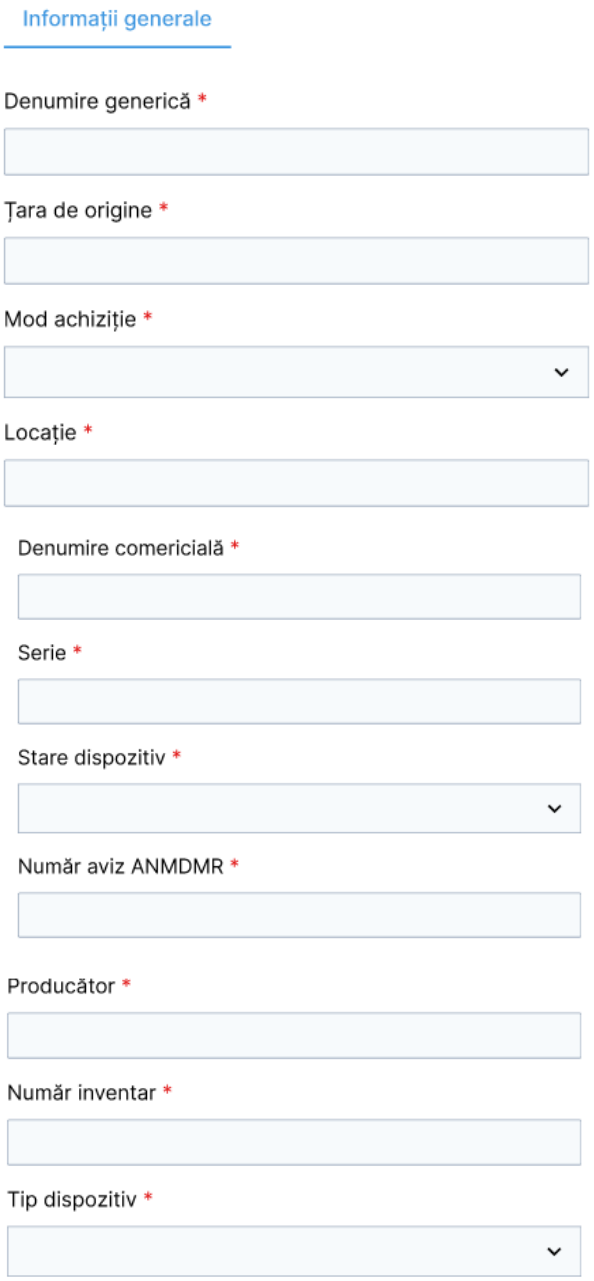

Figure 3. Medical devices inventory

Through the platform, biomedical engineers can streamline the process of filling out preventive maintenance reports. This is achievable through the automation of data input based on previously recorded inventory data. With the assistance of this automation, biomedical engineers can save time and reduce human errors that may occur during the manual report completion process.

The simplified form of a report is presented in Figure 4.

Furthermore, from the previous entries, data can be extracted for the following operations so that the staff can prioritize their activities. All upcoming activities will be visible in a calendar, and the biomedical engineer will receive notifications regarding these activities.

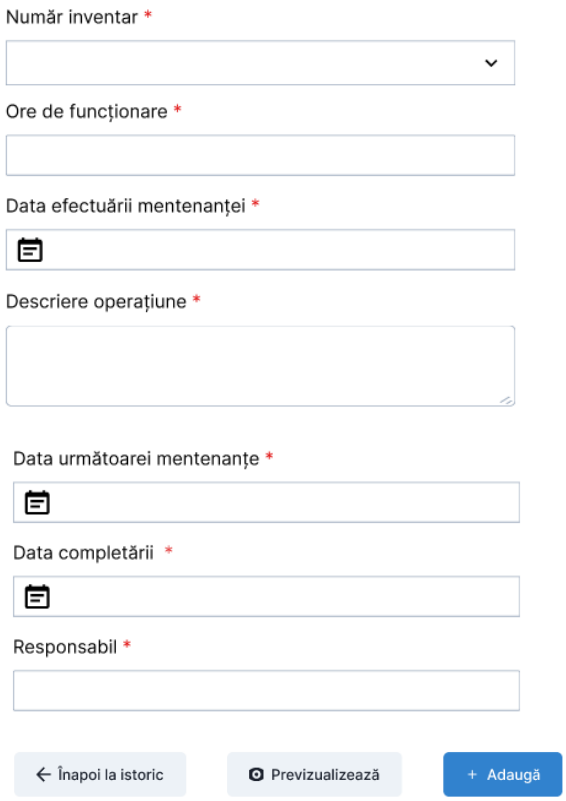

Figure 4. The simplified form of a preventive maintenance report

To enhance the efficiency of the department and assist in planning future activities, statistics regarding the frequency of failures and the status of medical devices can be tracked.

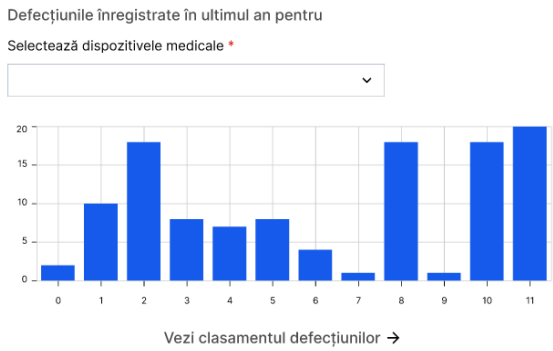

Figure 5. Statistics available in the platform

Considering the functionalities presented, in addition to its utility in healthcare facilities, this can also be used in an academic setting to familiarize students with the management of data related to medical devices.

IV. Conclusions

The transformation of medical device management through digitization is a vital step in the evolution of healthcare. Since there are current recommendations affirming the need for a CMMS, with the design of the web application in compliance with these guidelines and based on biomedical engineer's needs, we can conclude that the system created is a feasible solution and a necessity.

V. Bibliographic references

[1] World Health Organization, Human resources for medical devices, the role of biomedical engineers, World Health Organization, Geneva: Cataloguing-in-Publication, 2017, 113-125.
[2] Hilmi, Z.A., et al., A systematic review of medical equipment reliability assessment in improving the quality of healthcare services, Frontiers in Public Health, 9, 2019.
[3] Udroiu, G., Optimizarea programelor de mentenanță a dispozitivelor medicale, Buletinul Universității Naționale de Apărare "Carol I", 2021, 9(1):34-43.
[4] World Health Organization, (2011), Computerized maintenance management system, World Health Organization, 9-10.
[5] World Health Organization, Global atlas of medical devices, Geneva: WHO medical devices technical series, 2017, 95-470.
[6] World Health Organization, Global atlas of medical devices 2022, Geneva: WHO medical devices technical series, 2012, 2-388.

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Prioritization of Medical Equipment for Preventive Maintenance Decisions

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Abstract

Prioritizing medical equipment for maintenance decisions is crucial to ensure that healthcare facilities run smoothly, patient care is not disrupted, and patient safety is maintained. There are several factors to consider when prioritizing a particular medical equipment for maintenance. Among them, we mention: (A) risk assessment: identifying medical equipment with the greatest potential impact on patient safety or healthcare delivery and prioritizing their maintenance. (B) Use and Volume of Use: Assess the frequency and intensity of use of medical equipment and its impact on patient care. Equipment that is heavily used or critical to patient care should receive a higher priority. (C) User feedback: collecting feedback from staff who regularly use the equipment. They may notice problems or abnormalities that are not obvious through routine inspections. (D) Regulatory and Legal Requirements: Compliance with regulatory and legal requirements related to equipment maintenance. Equipment that must conform to standards or undergo periodic inspections should be prioritized accordingly. (E) Preventive maintenance program: developing a preventive maintenance program specific to each piece of medical equipment, determining the frequency of inspections and tests to prevent unexpected breakdowns. In this paper, we describe how the individual score values obtained for each functional criterion of a medical device can be used to establish guidelines of appropriate maintenance strategies for different classes of medical equipment.

Keywords: criticality prioritization, medical equipment, maintenance, decisions, risk

How to cite this article:
CORCIOVĂ C.P., BĂEȘU A.C., LUCA C., FUIOR R., "Prioritization of Medical Equipment for Preventive Manintenance Decisions", in *Bulletin of Micro and Nanoelectrotechnologies (BMNE)*, 2024, vol. 14, no. 1, pp. 11-13, ISSN 2069-1505.

1. Introduction

Prioritizing the maintenance of medical equipment is a crucial task to ensure the correct and safe operation of this equipment in a medical environment.

To be able to achieve this fact, the following aspects must be considered:

- Risk Assessment: identifying and assessing the risks associated with each piece of medical equipment are the first steps in prioritizing maintenance. Determining the degree of criticality of the equipment and the impact on patients in case of malfunctions are essential [1].
- Complete documentation: provide complete documentation for each medical device, including user manuals and manufacturer's recommended maintenance plans.
- Preventive Maintenance Schedule: establish a preventive maintenance schedule based on the manufacturer's recommendations. Higher risk or frequently used equipment may require shorter maintenance intervals [2].
- Performance monitoring: tracking key performance indicators (KPIs) for each piece of medical equipment, such as uptime, maintenance costs, and failure frequency helps identify equipment that needs special attention.
- level of use: medical equipment that is heavily used or that supports critical procedures must be carefully monitored. These should have a higher priority in the maintenance schedule.
- Stocks of spare parts: ensuring the stock of essential spare parts for medical equipment, the lack of these parts can lead to delays in maintenance [3].
- Prioritization based on impact: prioritization of maintenance should be based on the impact that equipment failure may have on patients, staff, and hospital or clinic operations [4] (Figure 1).

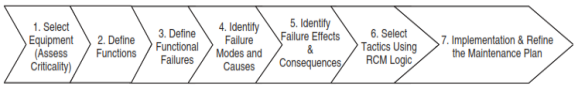

Figure 1. The logical chain of maintenance focused on reliability

The present work aims to analyse the score values obtained for each criterion that can be used to establish maintenance guidelines corresponding to strategies for different device classes. Information on 10 different medical devices is extracted from a hospital's maintenance management system to illustrate the application of the proposed model.

II. Materials and methods

Multi-criteria decision-making is a branch of decision-making, divided into multi-objective and multi-attribute decision-making. To achieve this, benchmark decisions such as evaluation, prioritization and selection with available alternatives characterized by multiple attributes are established. It is a three-step process: it decomposes a complex problem into a hierarchy, where the overall decision objective is at the top, and the criteria, subcriteria, and decision alternatives are at each descending level of the hierarchy consisting of specific factors [5-6]. Decision makers then compare each factor to all other factors at the same level of the hierarchy using a pairwise comparison matrix to find its relative weight or importance. The optimal solution is the alternative with the greatest cumulative weight. The model proposed is structured as follows:

1. identification of all sufficient, effective and independent criteria and sub-criteria for the evaluation of the device's criticality.

2. determination of the weighting values for all criteria and sub-criteria using the relative measurement method.

3. setting the grades and determining the intensities for each criterion using the relative measurement method.

4. evaluate alternatives (equipment or failure modes) according to each criterion and assign the most descriptive scores using the absolute measurement method; the intensity of the mark assigned for an alternative is called its score in relation to a criterion.

5. the criticality score for each medical equipment is calculated.

Evaluation criteria:

- c1 – Equipment function: the function of a device is the main purpose for which it is to be used.

- c2 - Mission criticality: mission criticality or operational impact describes the extent to which a device is essential to the delivery of care in a hospital process.

- c3 – Age: the age score is based on a device's actual age and its expected lifetime.

- c4 – Risk: Risk is one of the most important criteria for the criticality of a medical device, but it cannot be considered simply as having a single number assigned to a device. Rather, the device risk should be a sum of all risk values estimated from actual failures that have occurred in the device. All failure modes and their associated frequencies, consequences and detectabilities must be extracted or estimated from historical data and maintenance work of the medical device.

- c5 - Recalls and danger alerts: The number and class of recalls and the number of Danger Alerts that can occur for a device are important criteria in prioritizing medical devices.

- c6 - Maintenance requirements: Equipment that is predominantly mechanical, pneumatic, or fluid often requires the most maintenance. A device is considered to have a medium maintenance requirement if it requires only performance verification and safety testing.

Equipment receiving only visual inspection, a basic performance check and safety tests are classified as having minimal maintenance requirements.

Table I. Criteria/sub-criteria weighting values

Main criteria	Sub-criteria	Sub-criteria	Sub-criteria
c1 - Function (0.45)			
c2 - Mission criticality (0.10)	c21 - Utilization (0.70) c22 - Availability of alternatives devices (0.30)		
c3 - Age (0.06)			
c4 - Total risk (0.16)	c41 - Failure frequency (0.30) c42 - Detectability (0.24)		
	c43- Failure consequence (0.46)	c431- Operational (0.16) c432 - Non-operational (0.08) c433 - Safety and environment (0.76)	c4311 - Downtime (1.00) c4321- Cost of repair (1.00)
c5 - Recalls and hazard alerts (0.16)			
c6 - Maintenance requirement (0.07)			

III. Results and discussions

The proposed model prioritizes devices based on their criticality. The value of the normalized score indicates the relative criticality of a device in comparison to other devices. With such a model in mind, hospitals could focus their maintenance efforts on more critical devices. Devices with lower criticality scores could be removed from a maintenance management program, while devices

with high scores could be monitored and overseen.

Table II. Risk assessment of the failure modes

Device name	Frequency	Detectability	Consequence	Failure mode risk score	Total risk	Device risk
Sterilizer •Cassette jammed and punctured on plastic housing •Plaster is cracked	Frequent	Moderate	0.16	0.42	0.60	0.39
	Occasional	High	0.10	0.17		
Ventilator •Damaged power supply •Going to stand by during use	Occasional	Moderate	0.16	0.22	0.86	0.57
	Uncommon	Low	0.49	0.36		
Fetal monitor •Monitor not powering-up •Paper was not moving •The unit kept losing its configuration	Occasional	High	0.16	0.20	0.91	0.60
	Frequent	High	0.10	0.37		
	Occasional	Low	0.3	0.33		
Infant incubator •Audio alarms are not working •Missing access grommets •Motor is stuck	Frequent	Moderate	0.31	0.49	1.50	1.00
	Frequent	Low	0.14	0.44		
	Uncommon	Moderate	1.00	0.56		

IV. Conclusions

This paper presents a multi-criteria decision-making model to prioritize medical devices based on their criticality. Prioritizing medical devices according to their criticality is a crucial task in healthcare environments to ensure that resources and attention are allocated to the most important devices. A multi-criterion decision-making (MCDM) model can be used to systematically assess and rank medical devices based on various criteria. The specific details of the MCDM model may vary depending on the medical institution, the type of medical devices, and the data available. It is essential to involve relevant stakeholders and subject matter experts throughout the process to ensure the accuracy and relevance of the model.

V. Bibliographic references

[6] Raza, S., Standing, C., & Karim, A. (2015). Healthcare maintenance: Trends, issues, and challenges. International Journal of Healthcare Management, 8(3), 171-186.

[7] Dhillon, B. S., & Hoang, A. S. (2016). Total productive maintenance: A literature survey and directions. International Journal of Quality & Reliability Management, 33(7), 987-1014

[8] Joint Commission. (2019). Using Failure Mode and Effects Analysis (FMEA) to Improve Patient Safety. Sentinel Event Alert, 58.

[9] Yadin, M. A. (Ed.). (2015). Clinical Engineering Handbook. Academic Press.

[10] Barkaoui, Houssem & Rejeb, Helmi & Barkaoui, Abdelwahed & Tavares, Joao. (2023). Multi-Criteria Decision Making for Medical Device Development. 35. 102-119. 10.1080/10429247.2022.2040267.

[11] NIST. (2017). Medical Device Reliability. National Institute of Standards and Technology, from http://www.nist.gov/mml/acmd/biological_environments/medical-device-reliability2.cfm

[12] Floyd, M. K., Barker, K., Rocco, C. M., & Whitman, M. G. (2017). A Multi-Criteria Decision Analysis Technique for Stochastic Task Criticality in Project Management. Engineering Management Journal, 29(3), 165–178. https://doi.org/10.1080/10429247.2017.1340038

[13] ISO 55000 series on asset management standards.

[14] AAMI (Association for the Advancement of Medical Instrumentation) standards and guidelines.

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Interactive System for Cognitive Recovery by Means of Different Applications

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Abstract

Cognitive functions are active in all aspects of human existence. Autism and attention deficit disorder are just a few examples that affect language, play, cognition, social development, and coping skills, causing increasing delays compared to children of the same age. This significant increase in diagnoses of attention and memory disorders highlights the need to provide appropriate support and intervention in the educational system and in the community to help these children manage and overcome their difficulties. The emergence of recovery, as a border discipline between sciences such as neurology, psychology, pedagogy and social sciences, is the result of translating the demands of this methodological orientation, respectively, of the principle of interdisciplinary and complementarity. In cognitive-behavioural therapy patients will learn to identify, question and change thoughts, attitudes, beliefs and assumptions related to emotional and behavioural problems in relation to certain life situations. The approach and therapeutic strategies/techniques are complex, vary and are tailored to age and diagnosis so that it touches and solves each problem in a way as possible specific and with clear benefits for each patient.
The development of a specially designed system provides them with support and facilitates the most effective recovery, taking into account the individual needs of people and adapting them to the specific challenges they face in everyday life. Based on the recorded elements, the device provides real-time feedback in the form of visual signals that help users correct their attention and adjust their behaviour. Interactive games and virtual rewards were also included, it is done with the help of a tablet keeping the motivation and commitment of the subjects in using the system in the long term. Monitor and track progress in attention and behaviour management by generating customized reports for users or professionals involved.
Arduino development boards, strategically placed RGB colour sensors to detect and monitor emotional reactions, how to focus attention, an Arduino-controlled vibration motor for additional tactile stimulation have been integrated into the design and construction of the device.

Keywords: microcontroller, games interactive, rehabilitation, health improvement

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1. Introduction

The development of a device specially designed to help people with attention, memory and attention deficit hyperactivity disorder (ADHD) as an innovative solution to support and recover as efficiently as possible [1]. Based on the principles of cognitive and behavioural therapy, which have been shown to be effective in treating ADHD, I approached the design of the device from a holistic perspective, taking into account the individual needs of people and adapting to the specific challenges faced in everyday life with day [2]. Being me based on the recorded elements, the device provides real-time feedback in the form of visual signals that help users correct their attention and adjust their behaviour. We have also included gamification features such as interactive games and virtual rewards to keep users motivated and engaged in using the device in the long term [3].

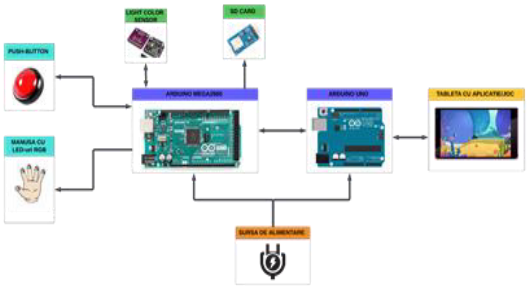


Figure 1. Block diagram of the device

II. Material and method

The design of the device has been completed by a dedicated software application that allows authorized persons to monitor and track progress in attention and behaviour management, plan tasks, and generate customized reports for users and specialists involved in their care.

In designing and making the device, several elements were integrated that contributed to its functionality and efficiency. To control and program, Arduino UNO and Arduino Mega 2560 development boards were used, which are the central bases of its input and output elements [4]. The use of RGB colour sensors was strategically placed to detect and monitor both the children's emotional reactions in the therapeutic activities and how the focus of attention is achieved. The Arduino Mega 2560 controlled vibration motor attached to the LED glove provides additional tactile stimulation, making the experience during therapy sessions interactive [5]. To integrate the hardware and software part, the display of different challenges according to the level of disorder is done with the help of a tablet containing games and tasks that stimulate their cognitive skills, attention, and emotional self-regulation.

The Arduino development board is an open-source platform based on the use of hardware and software. It is capable of reading inputs (for example: light on a sensor, a finger on a button, etc.) and transforming them into outputs (turning on an LED, activating a motor, etc.).

The ATmega2560 microcontroller on the Arduino Mega development board has an operating voltage of 5V, but with the help of a voltage stabilizer, it can be powered up to a voltage of 12V. It presents 54 input and output pins (external connections), 15 PWM (Pulse-width modulation) type pins through which we can acquire/transfer data, and 16 analogue pins. It also has 4 UART-type pins generally used for displaying information on the display. The flash memory is 256KB, of which 8KB is occupied by the bootloader with an operating frequency of 16MHz [6].

The Arduino Mega2560 can be powered via a USB connection or with an external power source. The board can operate on an external supply of 6 to 20 volts, but the recommended range is 7 to 12 volts because the voltage regulator can overheat and damage the board.

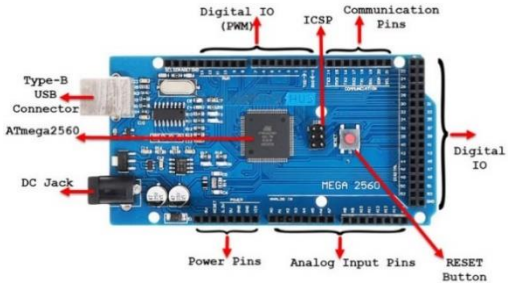


Figure 2. Arduino Mega 2560 development platform

The SD module allows the connection of an SD card in connectivity with a microcontroller to save the data obtained from the serial on the memory card, thus it will be possible to easily view the history with the score and the log of the registered order. Memory cards operate at a voltage of 3.3V, so a voltage regulator must be used to convert the 5V signal given by the Arduino into a 3.3V one. The module allows having an SD card with a maximum size of 2GB, and data formatting is performed in a FAT32 format (Figure 3) [7].

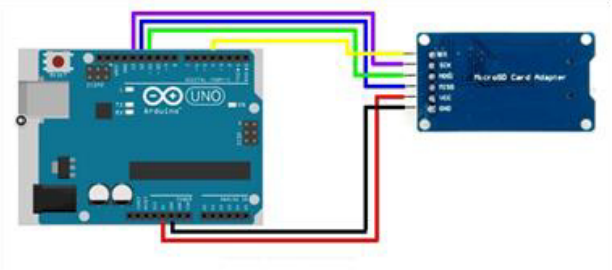


Figure 3. Principle of operation of the bending sensor

Through the game, which is based on a set of buttons of different shades, fine motor skills of the hands, spatial thinking, colour concept, as well as creativity, memory stimulation, attention, insight are trained. this is done by pushing the buttons that contain and unled that will light up the moment it is functionally activated according to the source code (Figure 4) [8].

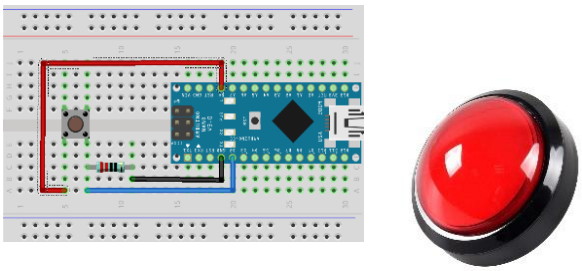


Figure 4. Connection diagram of the push-button with led

The glove is specially designed for the user's comfort and mobility in soft and flexible textile material, such as neoprene or synthetic fibers, which has attached LEDs of different colours and can create various lighting effects. Attached to the glove on the inside of the palm are RGB LEDs, which can produce light in three basic colours: red (R), green (G) and

blue (B) and can be controlled independently or simultaneously to create different shades of colours. [9]

On the outside of the hand is the vibration motor that generates vibrations and provides a haptic response when you press the push button corresponding to the RGB LED that lights up.

Figure 5. Placement of LEDs and RGB colour sensor

The light sensor (Red-Green-Blue) is used to detect and measure light levels in the three primary colours: red, green, and blue. Consisting of an array of photodiodes, each of which is sensitive to a specific colour. This allows obtaining a wide spectrum of information about the brightness of each colour range. Such sensors automatically adjust lighting based on ambient light conditions, automatically adjust white balance to achieve accurate colour reproduction, detect and analyse colours in photos, and images, create custom lighting effects, and set precision and colour fidelity in various applications [10].

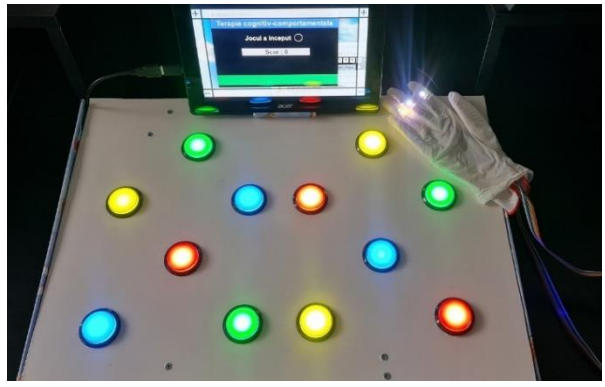
Figure 6. RGB colour sensor with IR filter

III. Results and discussions

The device is based on two Arduino development platforms, one with a higher processing level and another with a lower processing level. through which the interaction is made. The programming language is C++ and Java with the help of which the game was created, which aims to evaluate the subjects by displaying a score following the completion of the recovery session.

In order to have an overall view and to validate the design and practical realization of the cognitive recovery device, it is necessary to realize the software part. The software part consists of 2 parts: the implementation of the source code, which validates the connection method of the hardware part, and the work interface, the game made with the help of the Processing software. In this sense, the Arduino IDE programming environment was used, an integrated development environment based on the C++ programming language, being a cross-platform application written in Java.

In principle, the software part is based on two essential stages. The first stage concerns the algorithm that will light up the LEDs on the glove, respectively on the buttons, as well as the reaction time offered by the subject [11]. The second stage involves the validation of pressing the correct button through which the change in the score can be observed in the application.



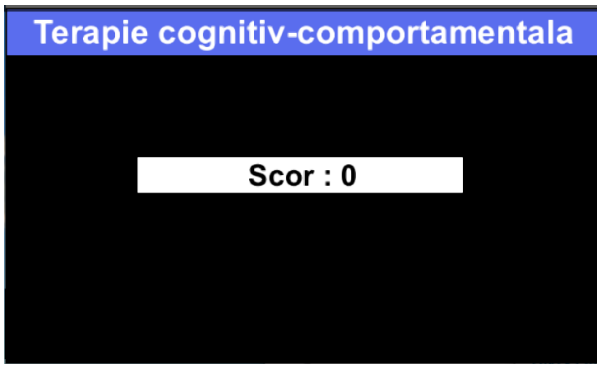


Figure 7. Overview - device test mode and app display in Processing

Through this project, we have demonstrated the need to introduce innovative medical devices that are in step with current technology in medical recovery centres, integrating digital technologies into traditional therapies to provide a personalized and effective approach [12].

A personalized therapy plan involves careful assessment of the individual's needs and abilities, considering factors such as age, developmental level, cognitive and physical abilities, and personal preferences [13]. Based on these assessments, an individualized plan is developed that includes therapeutic goals and appropriate strategies.

It can include different types of interventions, such as occupational therapy, play therapy, behavioural therapy, physical therapy or other specialized therapies, depending on the needs, with the aim of stimulating cognitive, motor, social and emotional development [14]. At the same time, it has different degrees of difficulty to allow the subject to adjust to the system, to perform as correctly and accurately as possible the movements of the recovery program established together with the physiotherapist.

Due to the fast-paced action, the subject is forced to make many decisions in a relatively short time, thus improving problem-solving skills and the ability to make quick and correct decisions, but the most important aspect, especially in the case of children, improving the capabilities and coordinating the movements performed [15].

Figure 8. Exercises required of the patient performed using the device

IV. Bibliographic references

[1] Danielson ML, Holbrook JR, Newsome K., Charania SN, McCord RF, Kogan MD, Blumberg SJ. State-level estimates of the prevalence of parent-reported ADHD diagnosis and treatment among U.S. children and adolescents, 2016–2019. Journal of Attention Disorders, published online May 22, 2022.

[2] American Psychiatric Association, Diagnostic and Statistical Manual of Mental Disorders. Diagnostic and Statistical Manual of Mental Disorders, 5th Edition. American Psychiatric Association; 2013.

[3] Roth RM, Saykin AJ. Executive dysfunction in attention - deficit / hyperactivity disorder: cognitive and neuroimaging findings. Psychiatr Clin North Am, 2004, 27: 83–96 (apud. Gorgos, 1987).

[4] Malenka RC, Nestler EJ, Hyman SE (2009). „Chapter 6: Widely Projecting Systems: Monoamines, Acetylcholine, and Orexin". În Sydor A, Brown RY. Molecular Neuropharmacology: A Foundation for Clinical Neuroscience (ed. 2nd). New York: McGraw-Hill Medical. pp. 148, 154–157. ISBN 978-0-07-148127-4.

[5] Bloom, B. S., Engelhart, M. D., Furst, E. J., Hill, W. H., & Krathwohl, D. (1956). Taxonomy of Educational Objectives: The Classification of Educational Goals. Handbook 1: Cognitive Domain. David McKay Company.

[6] Arduino Mega2560 - https://store.arduino.cc/products/arduino-mega-2560-rev3.

[7] SD Card - https://www.robotpark.com/SD-Card-Module.

[8] Anderson, L. W., & Krathwohl, D. (Eds.). (2001). A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives. Longman.

[9] Led RGB SMD - https://www.robofun.ro/ky-009-smd-3-color-led-module.htm.

[10] Senzor de culoare RGB - https://www.robofun.ro/senzori/senzor-de-culoare-rgb-cu-filtru-ir-tcs34725.htm.

[11] Nikolić, M., Dabić, T. (2016). The Bloom's Taxonomy Revisited in the Context of Online Tools. Paper presented at Sinteza 2016 - International Scientific Conference on ICT and E-Business Related Research. doi:10.15308/Sinteza-2016-315-320.

[12] Artterapia în recuperarea cognitivă - https://autismartaadhd.ro/artterapie/.

[13] Breben Silvia și colaboratorii, Metode interactive de grup, Ghid metodic, Ed. Arves, Craiova,2007.

[14] Activități integrate. Intrebari și răspunsuri, Editura Casa Corpului Didactic Cluj, Cluj-Napoca, 2009.

[15] Culea Laurenția Grama, Angela Filofteia, Activitatea integrată din grădiniță - ghid pentru cadrele didactice din învățământul preșcolar, Ed. Publishing House, 2008.

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Current Trends in the Treatment of Aortic Stenosis

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Abstract

Aortic stenosis is the most common valvular pathology leading to left ventricular outflow tract obstruction, with an increasing prevalence due to increasing life expectancy. Although with a low prevalence in the younger population, aortic stenosis can affect 2-7% of adults over 65 years of age. Severe aortic stenosis is found in approximately 3-4% of adults over 75 years of age.
Surgical aortic valve replacement has been the gold-standard of treatment in patients with severe aortic stenosis presenting with symptoms. Until recently, patients who were classified as high risk for surgery had limited therapeutic options, mainly symptomatic (diuretic therapy) and balloon valvuloplasty procedures. The main goal of these therapeutic strategies was palliative treatment and these interventions have not been shown to have an effect on long-term outcomes. The development of the transcatheter aortic valve replacement (TAVI) technique has changed the therapeutic perspective in patients previously considered inoperable by offering both an improvement in symptoms and a significant benefit on mortality.
The TAVI procedure is usually performed in a room with both operating room and cardiac catheterization laboratory capabilities. The team consists of an interventional cardiologist, cardiac surgeon and anesthesiologist. The procedure is performed under direct fluoroscopic visualization and occasionally in complex cases transesophageal echocardiography may be associated. The most widely used and least invasive abrod is the transfemoral approach. If this approach is not feasible, other, often more invasive approaches (apical, trans-aortic) can be used.
Multiple studies have demonstrated the superiority of transcatheter aortic valve replacement in terms of cardiovascular mortality, total mortality and symptomatology compared to surgical replacement. With this article we attempt to present current trends in the treatment of the patient with aortic stenosis.

Keywords: aortic stenosis, approach, mortality, prosthesis, transcatheter, team, velocity

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1. Introduction

Aortic stenosis is a very common form (the most common) valvuar pathology that has a prevalence of 0,5% in the general population and can affect up to 7% of adults over 65 years of age. Aortic stenosis is the leading cause of left ventricular outflow obstruction [1]. About 2 to 9% of patients aged greater than 75 years have severe aortic stenosis [2]. Other studies show that the prevalence of severe AS, for which intervention may be considered, may be as high as 3% to 4% in older adult (>75 years of age) populations [1].

Etiologies of aortic stenosis include congenital heart diseases (bicuspid/unicuspid), calcific and rheumatic disease. The most common causes of aortic stenosis are calcified (age-related) aortic stenosis and congenital bicuspid aortic valves. Infrequently aortic stenosis can be a result of rheumatic heart disease, despite the fact that this is more commonly a disease of the mitral valve and generally seen in developing countries. Calcified aortic stenosis is by far the most common etiology and is believed to occur via progressive endothelial damage, proliferative and inflammatory changes similar to atherosclerosis, caused by aging [2]. The causes of aortic stenosis vary geographically as calcific stenosis is more common in North America and Europe, while rheumatic valve disease is more common in developing countries [3].

Aortic stenosis can have a long latent asymptomatic phase, that can vary up to 20 years. After that, the first symptoms may appear gradually such as exertional dyspnoea or fatigue. During the asymptomatic phase the patients have a great survival rate. Patients continue to develop symptoms such as syncope, chest paint even heart failure.

Mortality increases reach up to 90% after only a few years of the onset of symptoms [2]. These patients need symptomatic therapy but the decisive treatment for aortic stenosis is represented by aortic valve replacement. There are two approaches, either via a surgical or percutaneous intervention.

2. Evaluation and indication

The primary modality of evaluation and diagnosis of aortic stenosis is transthoracic echocardiography. TTE evaluate the function of the left ventricle, the morphology (hypertrophy), aortic valve calcification and morphology. It is also used to measure the valve area and the velocities/gradients transvalvular.

Aortic stenosis is defined as severe when we measure a maximum velocity across the aortic valve over 4m/s and a mean transvalvular pressure gradient over 40mmHg. The aortic valvular area is normally below 1 cm2, and the area indexed to body surface is below 0,6 cm2 [4].

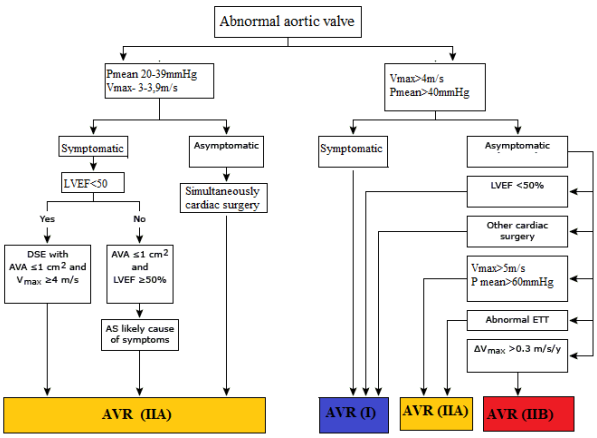

Figure 1. Management of patients with aortic stenosis

Management strategy for patients with severe aortic stenosis [5] is summarized in figure 1. Aortic valve replacement must be done in special prepared centres. Selection of surgical versus transcatheter intervention must be based on a detailed assessment of clinical, anatomical and interventional factors by the cardiac team, balancing the risks and benefits of each procedure on an individual basis. The Heart Team's advice should be explained to the patient, who can then make an appropriate decision.

Surgical valve replacement is suggested in younger individuals who are at low risk for surgery (<75 years and risk score EuroSCORE II <4%) or in patients who are candidates and ineligible for transfemoral approach [6]. Transcatheter aortic valve replacement is reserved for elderly patients (>_75 years), or in those at high risk (risk score EuroSCORE II>8%) or who are ineligible for classic aortic valvular surgery [7]. SAVR or TAVI will be considered for the remaining patients based on their specific clinical, anatomical and procedural characteristics. When the patient is unsuitable for transfemoral TAVI we can use other approaches (transaortic, trans-subclavian and transapical access).

3. Valvular replacement

Ballon valvuloplasty was once a traditional therapy for aortic stenosis, but the role of this intervention was diminished by the advent of new transcatheter therapies. Percutaneous balloon aortic valvuloplasty has a modest impact on the management of calcific aortic stenosis. Ballon valvuloplasty is first-line therapy in paediatric patients and younger adults with aortic stenosis due to congenital defects in the absence of significant valve calcification [8]. This is an efficacious therapy with short-term haemodynamic and symptomatic improvements, but a substantial restenosis incidence and no impact on long-term mortality. The main role of ballon valvuloplasty as a gateway to aortic valvular replacement (surgical or percutaneous) and as an essential palliative treatment for patients not suitable for conventional valve replacement [9].

When the surgical aortic valvular replacement is selected, we have many prosthetic options. Mechanical prosthesis has an easy implantation process and a long durability but requires lifetime anticoagulation and have frequent thromboembolic complications. The key benefit of mechanical prostheses is their endurance. Newer mechanical valves do not suffer from structural valve deterioration. That was demonstrated in multiple large studies with 25 years follow-up [10, 11].

Stented bioprosthetic prosthesis have a easy implantation and don't need long-term anticoagulation. Stentless bioprosthetic have an outstanding hemodynamics even in small annulus and have a very good durability as full root. In opposition to mechanical prosthesis, bioprosthetic prosthesis undergoes structural valve degeneration. A major trial of more than 1400 patients showed no difference in preoperative mortality between stented and stentless valves [12].

Homograft prosthesis is often used in endocarditis but have a relatively poor durability. Because of the rapid degradation in comparison to other options, homografts are no longer used as first-line therapy for aortic stenosis in contemporary times. Structural valve deterioration occurs in up to 80% of patients at 20 years after surgery [13].

Ross procedure have an excellent durability and hemodynamics outcome but is an isolated procedure with a high surgical complexity and a high perioperative mortality.

This procedure is the only method of replacing the aortic valve in which viable tissue is used to create the implant.

A recent review of the UK database in paediatric and young adults (<40 years) demonstrated a perioperative mortality of 1.1%, compared to mechanical AVR (2.0%), bioprosthetic AVR (2.6%) and homograft AVR (2.1%) [14].

Transcatheter aortic valve replacement has revolutionised aortic stenosis management over the past decade. Since 2011, TAVR has seen a reduction in 30-day mortality (7.2% to 2.5%), and stroke (2.75%

to 2.3%), with acceptable patient-reported outcomes achieved in 8 of 10 patients at 1 year [15]. All currently available transcatheter prosthetic valves have a similar fundamental structure, composed of a trileaflet pericardial bioprosthesis fixed to a metal stent that is positioned inside the native AV annulus. In contrast with surgical replacement which involves cardiopulmonary bypass and cardioplegic arrest, transcatheter replacement is performed often with local anaesthesia, with or without general sedation [16, 17].

A large study in USA that included patients >60 years old with aortic stenosis who underwent transcatheter or surgical aortic valve replacement identified a total of 867658 interventions between 1st January 2003 and 31 December 2016 [18]. The total volume of SAVR initially increased gradually from 45201 in 2003 to 58697 in 2011, but later declined to 51 355 in 2016. The proportion of TAVI among all valve replacement procedures increased remarkably from 11.9% in 2012 to 43.2% in 2016 (P<0.001) [18]. Especially TAVI was more pronounced in elderly patients. In the last year of the study, TAVI was the valve replacement procedure of choice in 97.3%, 72.2% and 26.9% of patients aged >90, between 80-90 and <80 years of age [18].

Using a French database, that included information about all aortic valve replacements done in France for aortic stenosis between 2007 and 2019, the incidence of aortic valvular replacement increased in a linear trend (from 10.892 to 23.109) because of a significant rise in transcatheter replacement (from 253 to 13.030), while surgical replacement increased until 2013 and then declined (10.892 in 2007 and 10.079 in 2019) [19].

Another study involving more than 50,000 patients from Poland concluded that the number of aortic valve procedures has doubled. Mortality was significantly lower with all types of AVR. The TAVI procedure has rapidly gained popularity [20].

A retrospective cohort study to evaluate trends in complications among patients aged ≥65 years treated with TAVR or SAVR between 2012 and 2019 demonstrated that complication rates following elective AVR decreased from 49% in 2012 to 22% in 2019. These decreases were more significant for TAVR (from 41% to 19%) than SAVR (from 51% to 47%) [21].

A Danish nationwide study concludes the number of AVRs grew from 2008 to 2020 as a result of the implementation of TAVI, which accounted for 2/3 of AVRs and over 70% of isolated AVRs [22].

Partner trial was a randomized prospective trial that divided patients into 2 cohorts: Partner A and Partner B. The Partner A cohort compared TAVR against SAVR in high-surgical-risk patients [23, 27]. Partner B included patients who were inegible for classic intervention because of combined risk of death or irreversible comorbidity [24, 27].

In Partner A trial the 30-day mortality rate for TAVR was 3.4% and for SAVR was 6.5%. Transchateter aortic valvular replacement was noninferiority. The 1-year mortality rate was 24.2% and 26.8% for TAVR and SAVR, respectively. In 5-year follow up the results were comparable as well, with mortality rates reported at 67.8% in the TAVR group versus 62.4% in the SAVR group [25].

In Partner B trial which evaluated TAVR versus medical therapy the results were substantially favourable to TAVR group. The 1-year mortality rate for TAVR was 30.7%, versus 50.7% for conventional medical therapy. The advantages of TAVR were maintained at 5 years follow-up with a lower mortality rate than medical treatment (71.8% vs 93.6%; P <0.0001) [26, 27].

4. Conclusions

Progress in transcatheter aortic valvular replacement has been a game-changer in the management of patients with aortic stenosis in recent years due to the ongoing advancement of procedural and device technology.

In people aged 75 years or older, TAVR should be considered as a first option. TAVR is recommended in patients who have prohibitive surgical risk and a predicted post-TAVR survival > 1 year.

5. Bibliographic references

[1] Douglas R. Johnston, Ahmad Zeeshan, Blaise A. Caraballo, 2018, Pages 269-276, ISBN 9780323478700, https://doi.org/10.1016/B978-0-323-47870-0.00029-5

[2] Wenn P, Zeltser R. Aortic Valve Disease. [Updated 2023 Jan 9]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan. https://www.ncbi.nlm.nih.gov/books/NBK542205/

[3] Pujari SH, Agasthi P. Aortic Stenosis. [Updated 2023 Apr 16]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan. https://www.ncbi.nlm.nih.gov/books/NBK557628/

[4] Otto CM, Nishimura RA, Bonow RO, Carabello BA, Erwin JP 3rd, Gentile F, Jneid H, Krieger EV, Mack M, McLeod C, et al. 2020 ACC/AHA guideline for the management of patients with valvular heart disease: a report of the American College of Cardiology/American Heart Association Joint Committee on Clinical Practice Guidelines. Circulation. 2021; 143:e72–e227. doi:10.1161/CIR.0000000000000923

[5] Alec Vahanian, Friedhelm Beyersdorf, Fabien Praz, et all. 2021 ESC/EACTS Guidelines for the management of valvular heart disease: Developed by the Task Force for the management of valvular heart disease of the European Society of Cardiology (ESC) and the European Association for Cardio-Thoracic Surgery (EACTS), *European Heart Journal*, Volume 43, Issue 7, 14 February 2022, Pages 561–632, https://doi.org/10.1093/eurheartj/ehab395

[6] Thourani VH, Suri RM, Gunter RL, Sheng S, et al. Contemporary real-world outcomes of surgical aortic valve replacement in 141,905 low-risk, intermediate-risk, and high-risk patients. Ann Thorac Surg 2015;9 9:5561.

[7] Gleason TG, Reardon MJ, Popma JJ et all ''5-Year outcomes of self-expanding transcatheter versus surgical aortic valve replacement in high-risk patients''. J Am Coll Cardiol 2018; 72:26872696.

[8] Ford TJ, Nguyen K, Brassil J, Kushwaha V, Friedman D, Allan R, Pitney M, Jepson N. Balloon Aortic Valvuloplasty in the Transcatheter Valve Era: Single Centre Indications and Early Safety Data in a High-Risk Population. Heart Lung Circ. 2018 May;27(5):595-600.

[9] Behan, Miles & Nadra, Imad & Thomas, Martyn & Redwood, Simon. (2010). Balloon aortic valvuloplasty: Review of the evidence and current indications. Interventional Cardiology. 2. 673-679. 10.2217/ica.10.64.

[10] Emery RW, Arom KV, Krogh C, Joyce LD. 1048-136 Long-term results with the St. Jude medical aortic valve: a 25-year experience. *J Am Coll Cardiol*. 2004; 43:A429.
[11] Emery RW, Krogh CC, Arom KV, Emery AM, Benyo-Albrecht K, Joyce LD, Nicoloff DM. The St. Jude Medical cardiac valve prosthesis: a 25-year experience with single valve replacement. *Ann Thorac Surg*. 2005; 79:776–782; discussion 782. doi: 10.1016/j.athoracsur.2004.08.047
[12] Florath I, Rosendahl UP, Mortasawi A, Bauer SF, Dalladaku F, Ennker IC, Ennker JC. Current determinants of operative mortality in 1400 patients requiring aortic valve replacement. *Ann Thorac Surg*. 2003; 76:75–83. doi: 10.1016/s0003-4975(03)00341-2
[13] El-Hamamsy I, Clark L, Stevens LM, Sarang Z, Melina G, Takkenberg JJ, Yacoub MH. Late outcomes following freestyle versus homograft aortic root replacement: results from a prospective randomized trial. *J Am Coll Cardiol*. 2010; 55:368–376. doi: 10.1016/j.jacc.2009.09.030
[14] Sharifulin R, Bogachev-Prokophiev A, Zheleznev S, Demin I, Pivkin A, Afanasyev A, Karaskov A. Factors impacting long-term pulmonary autograft durability after the Ross procedure. *J Thorac Cardiovasc Surg*. 2019; 157:134-141.e3. doi: 10.1016/j.jtcvs.2018.05.046
[15] Carroll JD, Mack MJ, Vemulapalli S, et al. STS-ACC TVT Registry of Transcatheter Aortic Valve Replacement. J Am Coll Cardiol. 2020 Nov 24;76(21):2492-2516. doi:10.1016/j. jacc.2020.09.595
[16] Bianco V, Gleason TG, Kilic A, Lee JS, Schindler JT, Rauso L, Arnold J, Joshi R, Navid F, Kliner D, et al. Open surgical access for transfemoral TAVR should not be a contraindication for conscious sedation. *J Cardiothorac Vasc Anesth*. 2019; 33:39–44. doi:10.1053/j.jvca.2018.05.036
[17] Fröhlich GM, Lansky AJ, Webb J, Roffi M, Toggweiler S, Reinthaler M, Wang D, Hutchinson N, Wendler O, Hildick-Smith D, et al. Local versus general anesthesia for transcatheter aortic valve implantation (TAVR)–systematic review and meta-analysis. *BMC Med*. 2014; 12:41. doi:10.1186/1741-7015-12-41
[18] Alkhouli M, Alqahtani F, Ziada KM, Aljohani S, Holmes DR, Mathew V. Contemporary trends in the management of aortic stenosis in the USA. Eur Heart J. 2020 Feb 21;41(8):921-928. doi: 10.1093/eurheartj/ehz568. PMID: 31408096
[19] Nguyen V, Willner N, Eltchaninoff H, Burwash IG, Michel M, Durand E, Gilard M, Dindorf C, Iung B, Cribier A, Vahanian A, Chevreul K, Messika-Zeitoun D. Trends in aortic valve replacement for aortic stenosis: a French nationwide study. Eur Heart J. 2022 Feb 12;43(7):666-679. doi: 10.1093/eurheartj/ehab773. PMID: 34849714
[20] Bartus K, Sadowski J, Litwinowicz R, Filip G et all Changing trends in aortic valve procedures over the past ten years-from mechanical prosthesis via stented bioprosthesis to TAVI procedures-analysis of 50,846 aortic valve cases based on a Polish National Cardiac Surgery Database. J Thorac Dis. 2019 Jun;11(6):2340-2349. doi: 10.21037/jtd.2019.06.04. PMID: 31372271; PMCID: PMC6626813
[21] Trends in Complications among Patients undergoing Aortic Valve Replacement (AVR) in the United States, James E. Harvey III, Samir R. Kapadia, David J. Cohen, Ankur Kalra, William Irish, Candace Gunnarsson, Michael Ryan, Soumya Chikermane, Christin Thompson, Rishi PurimedRxiv 2023.06.27.23291980; doi: https://doi.org/10.1101/2023.06.27.23291980
[22] Graversen PL, Butt JH, Østergaard L, *et al*, Changes in aortic valve replacement procedures in Denmark from 2008 to 2020 *Heart* 2023;109:557-563
[23] Smith CR, Leon MB, Mack MJ, Miller DC, Moses JW, Svensson L.G., et al. Transcatheter versus surgical aortic-valve replacement in high-risk patients. *N Engl J Med* 2011; 364 (23): 2187– 98
[24] Leon MB, Smith CR, Mack M, Miller DC, Moses JW, Svensson LG, et al. Transcatheter aortic-valve implantation for aortic stenosis in patients who cannot undergo surgery. *N Engl J Med* 2010; 363(17): 1597– 607
[25] Mack MJ, Leon MB, Smith CR, Miller DC, Moses JW, Tuzcu EM, et al. 5-year outcomes of transcatheter aortic valve replacement or surgical aortic valve replacement for high surgical risk patients with aortic stenosis (PARTNER 1): a randomised controlled trial. *Lancet* 2015; 385(9986): 2477– 84
[26] Kapadia SR, Leon MB, Makkar RR, Tuzcu EM, Svensson LG, Kodali S, et al. 5-year outcomes of transcatheter aortic valve replacement compared with standard treatment for patients with inoperable aortic stenosis (PARTNER 1): a randomised controlled trial. *Lancet* 2015; 385(9986): 2485– 91
[27] Arora S, Misenheimer JA, Ramaraj R. Transcatheter Aortic Valve Replacement: Comprehensive Review and Present Status. Tex Heart Inst J. 2017 Feb 1;44(1):29-38. doi: 10.14503/THIJ-16-5852. Erratum in: Tex Heart Inst J. 2018 Apr 7;45(2):122. PMID: 28265210; PMCID: PMC5317356

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Resetting the Brain. Remission of Neurocognitive Diseases is Possible!

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Abstract

For the first time, a large, randomized clinical trial has demonstrated a significant reduction in the risk for developing cognitive decline and dementia. The new research results show aggressive treatment of high blood pressure, resulting in fewer new cases of mild cognitive impairment and dementia. The future of dementia prevention could be in treating the whole person with a combination of drugs and lifestyle changes.

Keywords: Bredesen protocol, intermittent fasting, anti-inflammatory food, Alzheimer disease, beta-amyloid plaques reduced, neural cells, microtubule associate protein, tauopathy, oxidative stress

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The SPRINT MIND trial looked at two different approaches to controlling high blood pressure and diet and how that impacts mild cognitive impairment and dementia.

The Mediterranean diet emphasizes fruits, vegetables, whole grains, legumes, fish and seafood, unsaturated fats such as olive oils and low amounts of organic red meat, organic eggs and sweets.

The more specific diet, called Bredesen diet, is a method of combining intermittent fasting, eating anti-inflammatory foods, promoting gut health and avoiding diary and sugar. Eating foods like green leafy vegetables, fish, nuts and occasionally a glass of red wine can reduce the chances of developing Alzheimer disease. Eating strawberries, blueberries, acai fruit, apples, pears and bananas appears to counteract some of the declines in cognition, that were noticed in the latest research. Among plant protein derived amyloid, there are four legume source that are known to form amyloid-like fibrils: soybean, mung bean, fava bean and lupine.

The drinks that improve memory are: black coffee, green tea, kombucha, orange juice, blueberry juice, turmeric latte. Omega 3 fats, mainly DHA compound found in healthy fats, may help prevent Alzheimer disease and dementia by reducing beta-amyloid plaques. Food sources include cold water fish such as salmon, tuna, trout, mackerel, sardines and seaweed. In several pilot studies, a team of US researchers has discovered how vitamin D3, a form of vitamin D and Omega 3 fatty acids may help the immune system clear the brain of amyloid plaques, one of the physical hallmarks of Alzheimer disease. Lemon water is extremely hydrating and keeps the brain and entire body running optimally. Lemon contains high level of potassium, which allows more oxygen to reach the brain and improve functioning.

During the day, a person makes some beta amyloid protein builds in the brain. While sleeping, however, brain cells and their connections shrink, allowing more space between the brain cells, and so, beta amyloid and other substances that accumulate during the day, can be flushed away.

Amyloids can be reduced by consistent exercises such long walks, by good quality sleep, by reduced salt diet and foot massage.

Green tea catechins and resveratrol reduce the formation of plaques in the neural cells.

Increase in ketone bodies as a result of fasting

may reduce Beta amyloid level. Caloric restriction reduces both beta amyloid level and tau. Tau, the microtubule associated protein, forms insoluble filaments that accumulate as neurofibrillary tangles in Alzheimer disease.

Beta amyloid peptides are proteolytic fragments of the transmembrane precursor protein, whereas tau is a brain specific, acon enriched microtubule associated protein.

The pathological aggregation of tau or neurofibrillary tangles are known as tauopathy, a distinctive characteristic of many human neurodegenerative disease, such Alzheimer disease or Parkinson disease. Cinnamon can improve memory function and reduce the aggregation of tau proteins.

According to researchers at Wheeling Jesuit University, just smelling cinnamon can help improve the memory. Tau lesions occur earlier than beta amyloid accumulation, therefore the Alzheimer disease progression is strongly associated with tau pathology rather than beta amyloid protein accumulation. Tau, the soluble form, composed mostly of monomers and small oligomers are the neurotoxic species.

Turmeric, in its form as Curcumin, the active substance, has a great potential in the prevention and mainly in treatment of Alzheimer disease, due to its properties as an antioxidant, anti-inflammatory and lipophilic action.

Drinking warm eater before going to bed increases blood circulation, helps the body to break down the waste and increases the sweat output. Sweating will cause some fluid loss, but it will also remove the salts and toxins and clean the skin cells. Eating at specific times of the day could delay and even reverse the signs of Alzheimer disease.

Intermittent fasting (18-22 h a day and eating in a window of 2 h only) stimulates autophagy. Autophagy is a process where cells clean out damaged materials, and to rid the brain of toxic proteins like amyloid and tau, for example. Intermittent fasting can help increase the resistance of the brain to oxidative stress and inflammation.

The overall goal of Bredesen protocol is to remove exposure triggers that lead to cognitive decline, optimize health support and rebuild the neural network. Fat burning, based on minimum 12 h, exercising 30 minutes daily and eating a plant rich, fiber rich, low carbs and healthy fats, is very important. Alzheimer disease is associated with a decrease in glucose utilisation. Addressing insulin resistance and restoring insulin sensitivity, is also important, because insulin is a key growth factor for neurons.

Apart of the exercising, reducing stress, getting quality sleep, it is important to treat sleep apnea if present, to optimize essential nutrients, such as zinc and to take supplements such as berberine, cinnamon, alpha lipoic acid or chromium picolinate, in order to restore the insulin sensitivity. It is also important to optimize all nutrients, hormones and trophic (growth factor) support. Low levels of trophic factors such as vitamin B1, vitamin B12, vitamin D, testosterone, estrogen and nerve growth factor are associated with cognitive decline. For optimal cognitive function, vitamin C, vitamin E, vitamin K2, Omega 3, choline, zinc, magnesium, copper and selenium need to be considered.

The optimal brain function is also related to healthiest levels of thyroid, pregnenolone, estradiol, progesterone, testosterone, DHEA and cortisol.

Reducing inflammation is another target, because amyloids often associated with Alzheimer disease, are part of the body's inflammatory response. Leaky gut, just to give an example, is the most common cause of chronic inflammation.

Chronic inflammation generated or not by a leaky gut may also be caused by periodontitis (an inflammatory condition of the gums). Chronic periodontitis may be a direct cause of Alzheimer disease. Alcohol is a neurotoxin and should be avoided, animal diary and all kind of sugars.

Dementogens, the chemicals that contribute to cognitive decline, such as heavy metals, pollution, endocrine disruptors, can be identified by lab tests and the body must be detoxified. In this respect, plasmapheresis is one of the best options.

Conclusion

The brain has the ability to grow and adapt, a quality called neuroplasticity. Challenging our brains throughout our lives provides the opportunity for continuous growth. Choose to never stop learning and continue enriching your mind even after retirement.

Bibliographic References

[1] Bortolato B, Miskowiak KW, Köhler CA, Cognitive remission: a novel objective for the treatment of major depression? BMC Med. 2016; 14: 9.
[2] Stern Y Cognitive reserve in ageing and Alzheimer's disease. Lancet Neurol. 2012; 11(11): 1006-12.
[3] Dufouil C, Alperovitch A, Tzourio C. Influence of education on the relationship between white matter lesions and cognition. Neurology. 2003; 60(5): 831-6.
[4] Glatt SL, Hubble JP, Lyons K, et al. Risk factors for dementia in Parkinson's disease: effect of education. Neuroepidemiology. 1996; 15: 20-5.
[5] Podcasy JL, Epperson CN. Considering sex and gender in Alzheimer disease and other dementias. Dialogues Clin Neurosci 2016; 18: 437-46.
[6] Gale SA, Acar D, Daffner KR: Dementia. Am J Med 2018; 131: 1161-9.
[7] Lloret A, Esteve D, Lloret MA, et al. When does Alzheimer's disease really start? The role of biomarkers. Int J Mol Sci 2019; 20: 5536.
[8] Petersen RC, Lopez O, Armstrong MJ, et al.: Practice guideline update summary: mild cognitive impairment. Neurology 2018; 90:126-35.

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Mechanical Loads on the Circulatory System. Devices for the Removal of Blood Clots

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Abstract

The aim of this research project is to develop novel solutions for the removal of blood clots, as they are a highly intricate problem that affects millions of people every year, with complications spanning from ischemias and kidney failure to post-thrombotic syndrome, pulmonary embolisms and arteriovenous fistulas. At the moment, the main methods used for the treatment of blood clots include thrombolytic therapy and surgical thrombectomy, which can cause haemorrhages, kidney damage, embolisms, infections, ventricular arrythmias. Within the project we have developed two distinct parts: the theoretical part, beginning with an in-depth examination of the circulatory system, including the structural composition of blood vessels, the arteries, arterioles, veins, venules and capillaries. The vital role of blood components, including plasma, red blood cells, white blood cells, and platelets, in maintaining the chemical and physical properties of blood is highlighted, and a detailed study of hemodynamics is presented. Then, this knowledge is applied towards the development and realization of specialized clot removal devices, with a focus on tailoring these devices to the specific characteristics of different blood vessels.

Keywords: blood clots, Luer Lock, polyurethane, thrombectomy

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1. Approaching the topic

In the last century, humanity has seen tremendous advancements in the methods of visualization of blood vessels and removal of blood clots: the angioscopy (1924), the angiography (1926), thrombolytic therapy (1947), anticoagulants (1916), and surgical thrombectomy (1937). However, blood clots remain a widespread problem to this day.

In order to be able to bring novel solutions for their neutralization, we have had to study the properties of blood vessels and clots and to document current research and recent discoveries in the field.

2. The blood vessels

The walls of blood vessels are composed of three layers: tunica intima, tunica media, and tunica externa. Blood vessels come in five types: Arteries, which transport oxygenated blood to one or more parts of the body, except for the pulmonary artery, which carries deoxygenated blood from the right side of the heart to the lungs. There are two structural types of arteries, the first being the aorta and the pulmonary artery, with a diameter between 1 and 2.5 cm and a thickness of 1 mm, receiving blood directly from the heart. They are yellowish, exhibit increased distensibility due to large amounts of elastic fibers and membranes present in the media. The externa contains Vasa Vasorum, small blood vessels; the media contains numerous fenestrated elastic sheets, collagen, and few smooth muscle fibers. The intima is composed of an epithelium, along with a layer rich in elastin. The second type is muscular arteries, which distribute blood to various parts of the body. They have a diameter between 0.3 mm and 1 cm, with a thickness of 1 mm. They are red, sometimes white; compared to the first type, elastin is found between the intima and the media and between the media and the externa. The intima is composed of an endothelium. The media is mainly

composed of smooth muscle, containing elastin and collagen. The externa is wide, containing elastin and collagen. They are more active in vasoconstriction and less extensible.

Veins, with a diameter between 1mm and 3cm and a thickness of 0.5 mm, transport blood back to the heart that has lost over 80% of the systolic pressure. The walls have the same structure as arteries. Arterioles are branches of arteries, with a diameter between 10 μm and 0.3 mm. Capillaries, the smallest blood vessels, with a diameter of about 5-10 μm, facilitate the exchange of substances. Venules are small vessels through which blood returns from capillaries. Among these, blood clots can form into veins and arteries.

The elasticity of blood vessels depends on the materials that make up the vascular wall and their arrangement. Elastin is extremely extensible, with a Young's modulus of $6*10^6$ dyne/cm^2. Collagen, the main component of tendons, is inextensible, with an elastic modulus of 10^8 dyne/cm^2. The elastic modulus of smooth muscle is 10^6 dyne/cm^2, but it varies widely with the number of fibers in active contraction. These three components have different elastic properties, so the elasticity of the vessel largely depends on their arrangement and how they are connected. Collagen is arranged parallel to the other components and forms an interwoven network that becomes quite rigid when the vessel is stretched. In the aorta and proximal parts, elastin and smooth muscle are arranged in a complex structure that includes connections in series and parallel. In the rest of the arterial bed, they are not generally connected, with muscle attaching to muscle and elastin attaching to elastin in parallel arrangements. Thus, due to the inhomogeneity of the structure, Hooke's law is not applicable to blood vessels. In all vessels, the Young's modulus increases directly proportional to the enlargement of the radius, making the vessel more rigid as it widens. For moderate distensions, the characteristics and arrangement of muscle and elastin fibers are likely the main determinants of vessel elasticity. However, at maximum distension, it is observed that stress is predominantly placed on collagen, while another hypothesis suggests that vessels resemble elastomers.

In the vessels, flow is usually laminar, however, it can become turbulent, if the Reynolds Number reaches 2400:

$$R_e = \frac{v d \rho}{\eta} \tag{1}$$

where: v - blood speed, d - diameter of the vessel, ρ - density of blood, η - viscosity of blood. If the flow is continuous and laminar, the velocity of components within the same lamina can be calculated using the equation:

$$v_x = v_m\left(1 - \frac{x^2}{R^2}\right) \tag{2}$$

$$v_m = \frac{(P_A - P_B)R^2}{4\eta} \tag{3}$$

where: v_m - is the max speed, R - radius,

$P_A - P_B$ - presure gradient.

Using equation (1), we have calculated the Reynolds Number in different vessels of the body:

Table I. Calculations for Reynolds number

Vessel	R_e
Middle cerebral artery	505,8
Internal jugular vein	722,07
Common carotid artery	961,2
Thoracic aorta	9654,8
External iliac vein	83,286
Femural vein	1468,8

For the vessels with laminar flow, we have simulated the speed of the components using equation (2).

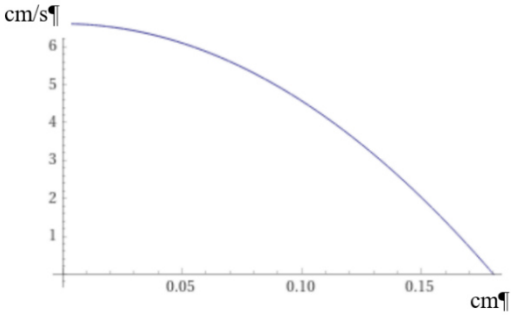

Figure 1. Simulation of blood speed inside EIV (V_m =6,51 cm/s, R=0,18 cm)

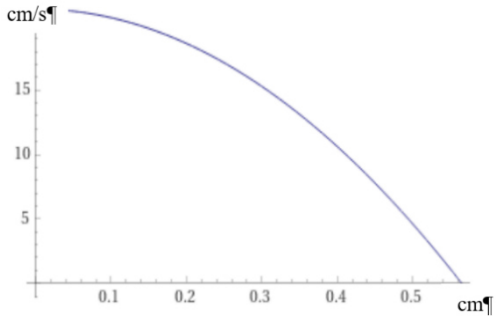

Figure 2. Simulation of blood speed inside IJV (V_m =21,3 cm/s, R=0,555 cm)

The resistance to flow can be calculated using the formula:

$$R_{es} = \frac{8\eta}{\pi R^4} \tag{4}$$

Series: $R_{tot} = R_1 + R_2 + R_3 + R_4 + ...$ (5)

Parallel: $\frac{1}{R_{tot}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + ...$ (6)

3. The initial system

The initial system was made of metal, with the lateral legs attached to the main body by Laser or TIG Microwelding.

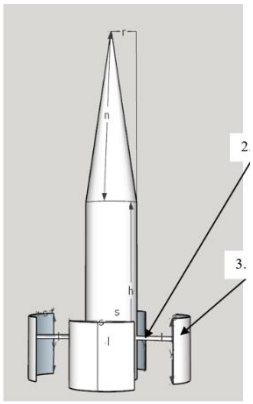

Figure 3. Lateral view of the system

Component 2 is a composed of a hollow metal tube with actuators made of electromagnetic coils with ferromagnetic core in alternating current that helps propel the system towards the blood clot.

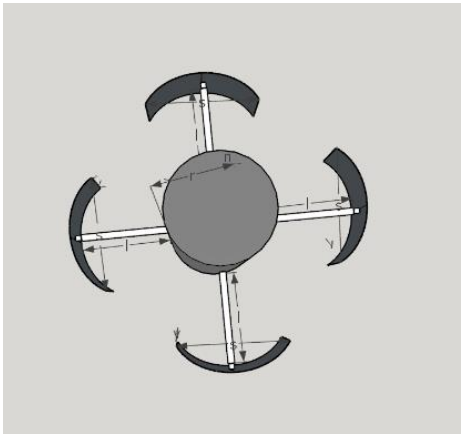

Figure 4. Downward view of the system

At the contact point between components 2 and 3, there is a microbar attached to component 3 (Fig. 3, Fig. 4), designed to slide, with the help of the actuator, in order to increase or decrease the diameter of the device, depending on the vein diameter.

Table II. Size of the components

Component	Size
h	10.79 mm – 32.5 mm
n	8.388 mm – 25.265 mm
s	6.58 mm – 19.3 mm
l	2.5 mm – 7 mm
y	4.98 mm – 15 mm
r	1.215 mm – 3.66 mm

Unfortunately, due to potential risks caused by embolization, difficulties in extracting the system upon usage, and the need for laminar flow to assure stability, the development process was stopped.

4. Current system

The device is composed of a polyurethane body with 2 coaxial hollow components, the exterior one connected to a Luer Lock syringe that acts as an aspirator, the interior one, connected to the distal tip, made out of rubber, with the role of transporting air to the distal tip in order to increase its volume.

Table II. Comparison of the characteristics of the 2 chosen materials

	Polyurethane	*Silicone*
Tensile Strength	25 MPa	0 MPa
Young's Modulus	6 MPa	3 MPa
Hardness	77.5 Shore	65 Shore
Yield Strength	0 MPa	0 MPa
Density	1250 kg/m^3	1250 kg/m^3

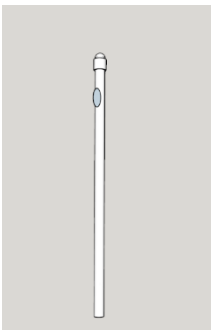

Figure 4. The system pre-penetration

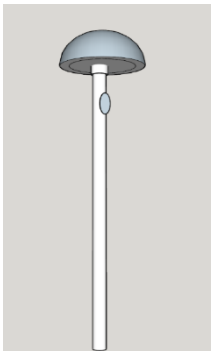

Figure 5. The system post-penetration

The system is introduced through a 4F-8F catheter sheath, after penetrating the clot completely, the airflow through the interior component is turned on. In order to keep

embolization from occurring and assure friction with the endothelium is kept minimal, the rubber will remain inflated until the finalization of the extraction and the external component will glide downwards, on the interior one, as in Figure 7.

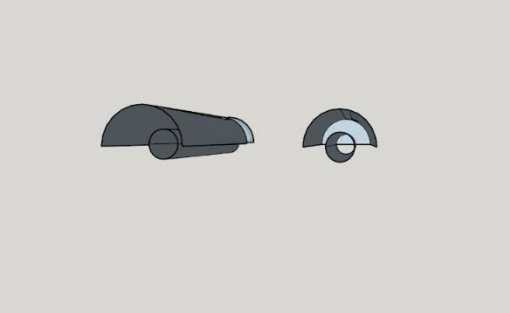

Figure 6. Bottom view of the system

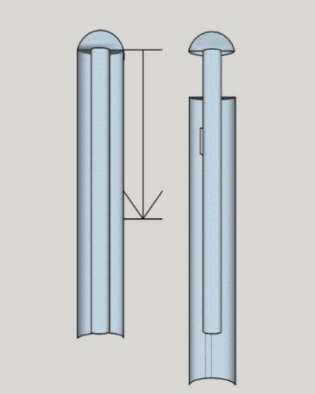

Figure 7. Cross-sectional view of the system

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6. Bibliographic References

[1] Abraham P, Arroyo DA, Giraud R, Bounameaux H, Bendjelid K., Understanding haemorrhagic risk following thrombolytic therapy in patients with intermediate-risk and high-risk pulmonary embolism: a hypothesis paper. Open Heart. 2018, doi: 10.1136/openhrt-2017-000735.

[2] Elaine Marieb, Human Anatomy & Physiology, San Francisco: Pearson Education, 2004.

[3] Joh JH, Park HC. The cutoff value of saphenous vein diameter to predict reflux. J Korean Surg Soc. 2013 Oct; 85(4):169-74. doi: 10.4174/jkss.2013.85.4.169. Epub 2013 Sep 30. PMID: 24106683; PMCID: PMC3791359.

[4] Blanco PJ, Müller LO, Spence JD., Blood pressure gradients in cerebral arteries: a clue to pathogenesis of cerebral small vessel disease. Stroke Vasc Neurol., 2017 Jun 8; 2(3):108-117. doi: 10.1136/svn-2017-000087. PMID: 28989801; PMCID: PMC5628379.

[5] Theodore C. Ruch, John F. Fulton, Medical Physiology and Biophysics, Philadelphia: W.B. Saunders Company, 1960.

[6] John E. Hall, Michael E. Hall, Guyton and Hall textbook of Medical Physiology, Philadelphia: Elsevier, 2021.

[7] Tseng YH, Chen CW, Wong MY, Yang TY, Lin YH, Lin BS, Huang YK., Blood Flow Analysis of the Great Saphenous Vein in the Su-Pine Position in Clinical Manifestations of Varicose Veins of Different Severities: Application of Phase-Contrast Magnetic Resonance Imaging Data. Diagnostics (Basel). 2022 Jan 5;12(1):118. doi: 10.3390/diagnostics12010118. PMID: 35054283; PMCID: PMC8774923.

[8] Munakomi S, M Das J. Neuroanatomy, Recurrent Artery of Heubner. [Updated 2022 Aug 29]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan. Available from: https://www.ncbi.nlm.nih.gov/books/NBK545222/

[9] Alan C. Heffner, Mark P. Androes, Placement of jugular venous catheters, Alphen Ana den Rijn: Wolters Kluwer, 2022.

[10] Bano S, Qadeer A, Akhtar A, Ata Ur-Rehman HM, Munawar K, Hussain SW, Khan MT, Zafar R. Measurement of Internal Jugular Vein and Common Carotid Artery Diameter Ratio by Ultrasound to Estimate Central Venous Pressure. Cureus, 2018 Mar 5; 10(3):e2277. doi: 10.7759/cureus.2277. PMID: 30949421; PMCID: PMC6440552.

[11] S. Galloway, A. Bodenham, Ultrasound imaging of the axillary vein—anatomical basis for central venous access, *BJA: British Journal of Anaesthesia*, Volume 90, Issue 5, May 2003, Pages 589–595, https://doi.org/10.1093/bja/aeg094

[12] Baz RA, Scheau C, Niscoveanu C, Bordei P., Morphometry of the Entire Internal Carotid Artery on CT Angiography. Medicina (Kaunas). 2021 Aug 17; 57(8):832. doi: 10.3390/medicina57080832. PMID: 34441039; PMCID: PMC8398484.

[13] Moawia Gameraddin, Normal abdominal aorta diameter on abdominal sonography in healthy asymptomatic adults: impact of age and gender, Journal of Radiation Research and Applied Sciences, Volume 12, Issue 1, 2019, Pages 186-191, ISSN 16878507, https://doi.org/10.1080/16878507.2019.1617553.

[14] Vernon B. Mountcastle, Medical Physiology, Saint Louis: The C.V Mosby Company, 1974.

[15] Elisabeth K. Beahm, Matthew M. Hanasono, Saleh Shenaq,CHAPTER 26 - Iliac flap, Editor(s): Fu-Chan Wei, Samir Mardini,Flaps and Reconstructive Surgery, W.B. Saunders, 2009, Pages 339-357, ISBN 9780721605197, https://doi.org/10.1016/B978-0-7216-0519-7.00026-5.(https://www.sciencedirect.com/science/article/pii/B9780721605197000265)

[16] Coffman JD, Lempert JA. Venous flow velocity, venous volume and arterial blood flow. Circulation. 1975 Jul; 52(1):141-5. doi: 10.1161/01.cir.52.1.141. PMID: 1132117.

[17] Keiler J, Seidel R, Wree A. The femoral vein diameter and its correlation with sex, age and body mass index – An anatomical parameter with clinical relevance. Phlebology. 2019; 34(1):58-69. doi:10.1177/0268355518772746

[18] Hertzberg BS, Kliewer MA, DeLong DM, Lalouche KJ, Paulson EK, Frederick MG, Carroll BA. Sonographic assessment of lower limb vein diameters: implications for the diagnosis and characterization of deep venous thrombosis. AJR Am J Roentgenol. 1997 May; 168(5):1253-7. doi: 10.2214/ajr.168.5.9129422. PMID: 9129422.

[19] Garcia J, van der Palen RLF, Bollache E, Jarvis K, Rose MJ, Barker AJ, Collins JD, Carr JC, Robinson J, Rigsby CK, Markl M. Distribution of blood flow velocity in the normal aorta: Effect of age and gender. J Magn Reson Imaging. 2018 Feb;47(2):487-498. doi: 10.1002/jmri.25773. Epub 2017 May 26. PMID: 28556277; PMCID: PMC5702593.

[20] Chang HW, Kim SH, Hakim AR, Chung S, Kim DJ, Lee JH, Kim JS, Lim C, Park KH. Diameter and growth rate of the thoracic aorta-analysis based on serial computed tomography scans. J Thorac Dis. 2020 Aug; 12(8):4002-4013. doi: 10.21037/jtd-20-1275. PMID: 32944312; PMCID: PMC7475554.

[21] Marr K, Jakimovski D, Mancini M, Carl E, Zivadinov R. Jugular Venous Flow Quantification Using Doppler Sonography. Ultrasound Med Biol. 2018 Aug; 44(8):1762-1769. doi: 10.1016/j.ultrasmedbio.2018.04.010. Epub 2018 May 18. PMID: 29784437; PMCID: PMC6026550.

[22] Billinger SA, Craig JC, Kwapiszeski SJ, Sisante JV, Vidoni ED, Maletsky R, Poole DC. Dynamics of middle cerebral

artery blood flow velocity during moderate-intensity exercise. J Appl Physiol (1985). 2017 May 1; 122(5):1125-1133. doi: 10.1152/japplphysiol.00995.2016. Epub 2017 Mar 9. PMID: 28280106; PMCID: PMC5451537.

[23] Rai AT, Hogg JP, Cline B, Hobbs G. Cerebrovascular geometry in the anterior circulation: an analysis of diameter, length and the vessel taper. J Neurointerv Surg. 2013.

[24] WOMERSLEY JR. Method for the calculation of velocity, rate of flow and viscous drag in arteries when the pressure gradient is known, *J Physiol*. 1955;127(3):553-563. doi:10.1113/jphysiol.1955.sp005276

[25] Anton Kasatkin, The changes in blood flow velocity in the internal jugular vein under conditions of variable intrapulmonic pressure and gravitational effect, 2023, doi: https://doi.org/10.1101/2023.07.28.551064.

[26] Arnost Fronek, Michael H. Criqui, Julie Denenberg, Robert D. Langer, Common femoral vein dimensions and hemodynamic including Valsalva response as a function of sex, age, and ethnicity in a population study, Journal of Vascular Surgery, Volume 33, Issue 5, 2001, Pages 1050-1056, ISSN 0741-5214, https://doi.org/10.1067/mva.2001.113496.

[27] Califf RM, Fortin DF, Tenaglia AN, Sane DC. Clinical risks of thrombolytic therapy. Am J Cardiol. 1992 Jan 3;69(2):12A-20A. doi: 10.1016/0002-9149(92)91168-4. PMID: 1729875.

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Investigating Mineral Metabolism in People of Different Ages using the MS Mass Spectroscopy Method

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Abstract

Determining the trace element levels in the human hair is a significant analytical technique, a screening element in the evaluation of possible deficiencies, excesses, and/or biochemical imbalances in all bodies of these microelements.
In this work of research, by an inductively coupled plasma– mass spectrometry (ICP-MS) analyser, the authors have proposed the discovery of toxic trace elements (Al, Pb, Hg) and levels principal mineral elements (Ca, Mg, Cu, Zn) from the human body on healthy individuals with a good nutritional status.
The study was performed on a sample of 75 adult women (30-35 years old) from different regions of the country, by taking 100 mg of hair from the base of the scalp with a length of 3 cm, for analysis and evaluation of trace elements.
Twelve patients (16%) had high mean values of intracellular Mg (1.2 mmol / L), high Ca values (0.72 mmol / L), but low mean Ca / Mg ratios, (0.58). In addition, six patients (8%) had low mean values of Mg (0.004 mmol / L) and Ca (0.04 mmol / L) but a high Ca / Mg ratio. At the moment of analysis, all individuals did not have acute or severe intoxication signs with heavy metals.
The environmental lifestyle of analysed individuals, from various areas of the country, was observed in their hair cells, by present levels of trace elements.

Keywords: Hair analysis, ICP-MS, nutritive metals, toxic metals

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1. Introduction

Mineral analysis of chemical elements in hairs has been shown to be useful in assessing general health. The evaluation of the trace elements in the hair can be useful in the diagnosis of diseases such as cancer, checks in forensic medicine, the examination of malnutrition and the evaluation of possible deficiencies, excesses or biochemical imbalances of the chemical elements in the body. The essential characteristic of the analysis method, Mass Spectroscopy used in hair analysis, is the determination of the level of minerals stored in the cells and interstitial spaces of the tissues of the human body, stationary in concentration over a period of 2-3 months.

2. Material and method

For almost 30 years, inductively coupled plasma-mass spectrometry (ICP-MS) has gained importance in laboratories around the world as a tool of choice for performing the analysis of trace elements in the human organism. Testing performed by conventional inductively coupled plasma mass spectroscopy (IPC-MS; Perkin Elmer 900), can analyse the concentration of mineral elements and metals in residual hair samples digested with chemical reagents, with results calculated according to the equivalence of 1 part per million (ppm} = 1 mg/dL.

Principles of measurements in mass spectrometry. In the Mass Spectrometry (MS), molecules are bombarded with a beam of energetic electrons. The molecules are ionized and broken up

into many fragments, some of which are positive ions. Each kind of ion has a particular ratio of mass to charge, or m/z value. If one electron is removed from the parent molecule, there is produced the molecular ion (or parent ions), whose m/z value is, of course, the molecular weight of compound; ex. M + e^{-} = M+ + 2 e. The linear dynamic range is the range over which ion signal is linear with analyse concentration. Next, the plasma ionizes these atoms can be detected by the mass spectrometer.

In the field of oncology, carcinogenic substances present the greatest health risk of all hazardous materials, because the failure of protective measures when working with these substances can only become apparent decades later in cancers, unlike immediately identifiable failures in acute mode. Through this method, laboratories can effectively use technical protective measures to minimize exposure to various toxic and carcinogenic agents [1].

This research paper aims to discover the levels of main mineral elements (Ca, Mg, Cu, Zn) and toxic trace elements (Al, Pb, Hg) in the human body, using the inductively coupled plasma technique in mass spectrometry (ICP-MS), in apparently healthy people, in the stage with a good nutritional status, without personal antecedents of exposure to toxic substances. A total of 75 people, adult women, in the age range of 30-55 years, from different regions of the country, were taken hair samples of 100 mg, obtained by cutting the first 3 cm of hair from the occipital region of the scalp [2].

Only the hair closest to the scalp is used to obtain information on nutrient status over the past 6 to 8 weeks. The importance of the method lies in the fact that a hair tissue mineral analysis is non-invasive and is more stable than blood analyses, because they are subject to daily variations in metabolite concentrations and sometimes vary from hour to hour [3].

3. Results

A number of 12 patients (16%) had high mean values of trace elements, intracellular Mg (1.2 mmol/L), high values of Ca (0.72 mmol/L), but low mean Ca/Mg ratios, (0.58). The environment and lifestyle of the people analysed, from different regions of the country, were reflected in the hair cells, just like in all the cells of the body. Also, six patients (8%) had values low averages of Mg (0.004 mmol/L) and Ca (0.04 mmol/L), but a high Ca/Mg ratio. At the time of analysis, all these persons showed no signs of acute or chronic intoxication with toxic metals, [Table 1].

Table 1. Database of ICP-MS; Perkin Elmer 90

No pacient	Concentrations (Mean Value)				Reports Mean Value
No. Crt.	Ca (ppb)	Ca (mmol/L)	Mg (ppb)	Mg (mmol/L)	Ca/Mg ppb
55	397.50	0.15	81.48	0.06	4.87 ppb
12	558.45	0.29	335.8	0.4	1.66 ppb
8	149.50	0.07	200.1	0.02	0.74 ppb
Reference	22-97 ppm male 18-47 ppm female		2-11 ppm 2-18 ppm		6.77 ppb 6.80 ppb

Magnesium, which is the second most abundant intracellular cation after potassium, plays a key role in the regulation of many cellular functions and enzymes, including ion channels, metabolic cycles, and signalling pathways. Serum Mg level is increased by release of Mg^{2+} from malignant tissues in patients with malignant disease before treatment with cytostatic drugs. In malignant cells, the transformation of pyruvic acid into lactic acid altered the process of glycolysis from the aerobic to the anaerobic pathway. Neoplastic conditions promote high intracellular production of LDH and increased utilization of Mg^{2} + during multiple molecular syntheses with the reaction, pyruvate acid > LDH/NADH > lactic acid + NAD, [4].

The understanding of intracellular Mg concentration and distribution has also been facilitated by the development of electron microprobe and fluorescent dye analysis techniques using micro-fluorescence spectrometry. Intracellular Mg is predominantly complexed with organic molecules, for example, adenosine triphosphatase, (ATP]), proteins associated with cell and nuclear membranes, DNA and RNA, enzymes, proteins and citrates) or sequestered in subcellular organelles, mitochondria and endoplasmic reticulum [5].

Other potential mechanisms affecting cytosolic Mg include a hypothetical Ca^{2+}-Mg^{2+} exchanger located in the endoplasmic reticulum, (ER), and transport proteins that may allow Mg to accumulate in the nucleus or ER. There must be a balance between the passive entry of Mg into the cell and an active efflux mechanism because the concentration gradient favours the movement of extracellular Mg (0.007–0.12 mmol/d L) into the cell (free Mg, ^{2}÷ 0.05 mmol/ dL [6].

Ca^{2+} ion is also an important regulatory ion, and alteration of mitochondrial homeostasis can lead to cellular dysfunction and apoptosis. Ca^{2+} is transported into respiratory mitochondria via the mitochondrial ion channel, the Ca2+ uni-porter, which is known to be inhibited by Mg^{2+}. Only 1% to 3% of total intracellular Mg exists as free ionized form as Mg_{+}^{2}, which has a tightly regulated concentration of 0.05 to 0.1 mmol/day L. Total cellular Mg concentration can vary from 0.55 to 2

mmol/day L, depending on the type of tissue studied, with the highest concentrations of Mg found in skeletal and cardiac muscle cells [7].

The effects of the calcium ion are triggered by the activation of receptors on the cell surface. These stimulate the production of inositol-1,4,5-triphosphate (IP3), which diffuses through the cytosol and activates internal P3-sensitive receptors (IP3R) that open and allow the release of Ca^{2}÷. The low concentration of Ca^{2}÷ is restored by means of ion pumps and anti-porter pumps. Pumps are found both on the plasma membrane and on the surface of the endoplasmic reticulum, (ER). Ca^{2}+ entry occurs through a low-affinity uniporter (U) due to the high electronegative potential (−180mV) in the mitochondrial matrix. Expulsion of Ca^{2}+ occurs via an electroneutral anti-porter, (instead with either Na+ mNCX or H+ mHCX), [Figure 1], [8].

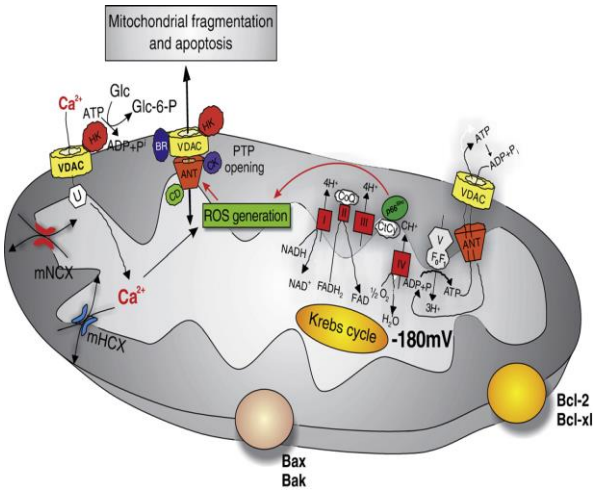

Figure 1. In the matrix, Ca^{2}+ stimulates the activity of three Ca^{2}+-sensitive dehydrogenase enzymes of the Krebs cycle thereby promoting electron flow through the voltage-dependent electron transport chain. from the anion channel (VDAC)

Diseases, without high values of toxic heavy metals, (tetany, renal failure, rickets infection, osteomalacia, vitamin D deficiency, hypoparathyroidism), suggesting that the interaction between magnesium and calcium. play a role in the pathogenesis and progression of these chronic diseases to a more clinically relevant phase.

Previous studies have shown that a high serum calcium/magnesium ratio) leads to inflammation and insulin resistance processes that have been linked to the progression of various forms of cancer. Critical values are also very well established. trace values or of heavy metals in the human body.

Normal values for Cu (normal range = 1-2 µg/day) and Zn (normal range = 3.5-6.7 µg/day L) were measured in 49 people, high values for Cu and Zn showed 22 of people and only 4 people with low values for Cu and Z. Zn/Cu ratio was recorded in 55 people, high values of Zn/Cu ratio in 5 people and low value of Zn/Cu ratio in 15 people. According to the researchers, the zinc atom could increase the immune response by stimulating phagocytosis and preventing T-lymphocyte apoptosis. Zinc deficiency has been found to compromise immunity through a number of mechanisms, such as T-cell dysfunction and dysregulation of phagocytosis with intracellular killing of bacteria.

The normal values for heavy metals, Hg, Pb, Al, were measured in 53 people and in 22 people values higher than the normal values were presented in a completely healthy organism without showing cases of heavy metal poisoning, (value normal Pb = 0.3-0.45 µg/day L; Al, normal value = 0.15-0.21, Hg, normal value = 0.63-0.99 µg/day L.

Blood mercury, Hg, normal values: <10 ng/ml, biological tolerance limit (LBT) = 10 ng/ml, Toxic level> 150 ng/ml, Lethal level> 800 ng/ml, pathological growth: symptomatic triad - dysfunctions articulation, disruption of muscle activity, narrowing of the visual field, severe and irreversible damage to the CNS.

Lead in blood: Pb, critical values > 30 ng/ml; Values > 60 ng/ml to initiate chelation therapy, values > 80 ng/ml medical emergency, pathological growth: intoxications: apathy, irritability, physical fatigue, anorexia, myalgia, delta-amino-levulinic acid increases, urinary free erythrocyte protoporphyrin increases, dehydratase of amino-levulinic acid decreases, anemia with reticulocytosis and basophilic punctate, neurotoxicity: ataxia, muscle weakness, convulsions, stupor, coma. Aluminum in blood, Al downstream normal: <10 ng/ml, dialysis patients, acceptable <60 ng/ml, concern <100 ng/ml, toxic > 200 ng/ml; pathological level: renal, osteomalacia, encephalopathy.

The Romanian Waters Law allows the following values (µg/L): Copper < 100, Mercury < 1, Aluminium < 200, Lead < 10, Calcium < 100 mg/L, Magnesium <50, Zinc < 5.

4. Conclusions

The ratio of values between calcium and magnesium can be associated with various metabolic diseases, even without high values of toxic heavy metals, suggesting that the interaction between magnesium and calcium plays a potential role in the pathogenesis and progression of chronic disease to a more clinically relevant phase.

The environment and lifestyle of the inhabitants of different regions of the country, the way of eating, the concentrations of mineral elements or heavy metals in the inhaled air or drinking water are reflected in the cells of the hair bulb, as in all the cells of the human body, in the concentrations of the last 3-4 months.

5. Bibliographic References

[1] Laboratory Analysis Provided by Trace Elements, Inc., an H. H. S. Licensed Clinical Laboratory, Introduction to hair tissue mineral analysis (htma) FNo. 45 D0481787 https://www.mineralcheck.com/wp-content/uploads/2019/02/SAMPLE-SUSIE-HOUSE-1.pdfle https://www.mineralstate.co.uk/wp-content/uploads/hair-analysis.pdf, accessed in March 2021.

[2] Udristioiu A, Giubelan A, Nica-Badea D. Determination of Trace Elements in Hair Analysis Using ICP-MASS Spectromery. Pharmacophore, 12(3) 2021; 54-59.
[3] Nas F, Hashim Z, Jalaudin J, How J, Hashim JH. The Determination of Heavy Metals Cocentration in Hair by Inductively Coupled Plasma Mass Spectrometry (ICP-MS), J. Environ. Anal. Toxicol, 9(1), 2019, 598.
[4] Ozmen H, Akarsu S, Polat F, Cukurovali A. The levels of calcium and magnesium, and of selected trace elements, in whole blood and scalp hair of children with growth retardation. Iran J. Pediatr., 23(2), 2013, 125–30.
[5] Faller, EM., Hernandez, MT., Hernandez, AM., Gabriel, JR. Emerging Roles of Pharmacists in Global Health: An Exploratory Study on their Knowledge, Perception, and Competency. Arch.
[6] Pradhan RK, Feng Q, Daniel A. Dash KD. Characterization of Mg2+ Inhibition of Mitochondrial Ca2+. Uptake by a mechanistic model of mitochondrial Ca2+ uniporter. Biophys J 2010.
[7] Mohammed MS, Tawfiq NF, Aziz Al-Ani LA. Assessment the Heavy elements in Policemen's Serum using FAAS. Sci. Eng 2020; 928 072143. IOP Conference Series: Materials Science and Engineering, Volume 928, 2nd International Scientific Conference of Al-Ayen University (ISCAU-2020), 15-16 July 2020.Pharm Pract., 11(1), 2020, 40-46.
[8] Johnson JD, Mehus JG, Tews K, Milavetz BI, Lambeth DO. Genetic evidence for the expression of ATP- and GTP-specific succinyl-CoA synthetases in multicellular eucaryotes". J. Biol. Chem 1998; 273 (42): 27580–6.

6. Authors' Biographies

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The Study of the Theorems of Ponderomotive Forces for the Identification of New Electromechanical Actuation Effects

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Abstract

In this paper we try to combine different standard electromechanical actuators to obtain hybrid actuators. Hybrid actuators may have better performances than standard ones, having a larger actuation domain or better precision. For this we first study the theoretical possibilities of combining actuators based on the theorems of ponderomotive actuations. Then we experimentally study some types of actuators and draw conclusions about each to see which combination might give promising results. In the end we build a hybrid actuator and measure it' s properties trying to fully characterize the system properties.

Keywords: hybrid actuators, electrostrictive materials, ponderomotive forces, precise positioning, unconventional actuators

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I. Introduction

An actuator [5] is a movement control mechanism. Depending on the type of actuator, it can transform a type of energy (eg: chemical, electromagnetic, thermal) into mechanical energy.

The theorems of ponderomotive actuations describe the forces exerted on a specific material in an electric field [1]:

$$\overline{f_{el}} = \rho_v \overline{E} - \frac{E^2}{2} grad\varepsilon + \frac{1}{2} grad\left(E^2 \frac{\delta\varepsilon}{\partial\tau}\tau \right) \quad (1)$$

and magnetic field:

$$\overline{f}_m = \overline{J} x \overline{B} - \frac{1}{2} H^2 grad\mu + \frac{1}{2} grad\left(H^2 \frac{\partial\mu}{\partial\tau}\tau \right) \quad (2)$$

Here we distinguish 3 independent terms of each force, describing 3 types of actuations based on electric and respectively magnetic field. Starting from these formulas, we want to combine two (or even more) independent actuations and see which of them give better results in terms of actuation precision and domain. Finally, we want to build some hybrid actuators and measure their properties such as the displacement-voltage characteristic for each component and establish some applications.

II. The new variants of electromechanical actuators - state of art

One of the major goals of research in the field is the creation of machines and micro-robots that can perform different tasks in very small spaces. The researchers mainly explored motors based on electrostatic, magnetic and piezoelectric phenomena. Since research for silicon-based MEMS micromotors began in the 1980s, a multitude of electrostatic micromotors have been tested. The first promising electrostatic motors were those with variable capacity. An alternative to these motors developed in the 1980s are the motors with electrostatic induction [2]. A simple model is the one in the figure in which the rotor is covered by a conductive layer and there are several electrodes on the stator. By applying a potential wave on the stator, image charges will form on the rotor and due to their attraction, a torque appears that acts on the rotor.

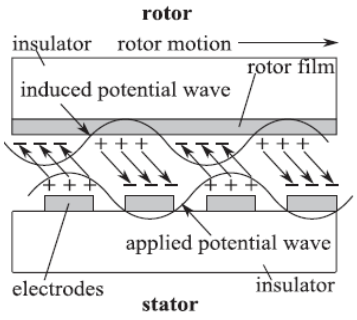

Figure 1. Electrostatic induction motor

As far as piezoelectric motors are concerned, most of them are designed to be used in a resonance regime that is reached at high frequencies, that's why they are considered ultrasonic motors. Various models can generate torques starting from a few nNm up to mNm.

One type of piezoelectric actuator is the multilayer actuator [3] composed of approximately 100 piezoelectric blades separated by electrodes. It has a short response time (10 μs) and generates large forces (~1000N) for low voltages(100V), but the displacements are relatively small (10 μm).

In the past years the interest in research on materials such as elastomers and collagen membranes has increased significantly. Most of them have piezoelectric or electrostrictive properties. The main point of researching them is that they may resist harsh conditions or high voltages better than classic piezoelectric materials such as PZT. Also, some of them give a better response regarding deformation per unit voltage.

All the above actuations are triggered by electric fields and the displacements generated are small (of the order of a few micrometres). Electromagnets and magnetostrictive actuators on the other hand generate strong forces and high displacements of the order of a few millimetres. Some applications of magnetostrictive actuators include ultrasonic acoustic devices used for generating powerful waves underwater and sensing configurations such as a non-contact strain sensor which provides a great strain mapping capability. [4]

III. Theoretical aspects about hybrid actuators

Using the table below we can identify 3 hybrid actuations involving only the electric field activated actuations:

Table 1. Analysis of possible combinations of electric forces

	$\overline{f_{e1}}$	$\overline{f_{e2}}$	$\overline{f_{e3}}$
$\overline{f_{e1}}$	X	$\overline{f_{e12}}$	$\overline{f_{e13}}$
$\overline{f_{e2}}$	$\overline{f_{e21}}$	X	$\overline{f_{e23}}$
$\overline{f_{e3}}$	$\overline{f_{e31}}$	$\overline{f_{e32}}$	X

The same goes for the actuations activated only by the magnetic field:

Table 2. Analysis of possible combinations of magnetic forces

	$\overline{f_{m1}}$	$\overline{f_{m2}}$	$\overline{f_{m3}}$
$\overline{f_{m1}}$	X	$\overline{f_{m12}}$	$\overline{f_{m13}}$
$\overline{f_{m2}}$	$\overline{f_{m21}}$	X	$\overline{f_{m23}}$
$\overline{f_{m3}}$	$\overline{f_{m31}}$	$\overline{f_{m32}}$	X

Also, there are possibilities of combining actuators based on magnetic effects and electric effects:

Table 3. Analysis of possible combinations between magnetic and electric forces

	$\overline{f_{m1}}$	$\overline{f_{m2}}$	$\overline{f_{m3}}$
$\overline{f_{e1}}$	$\overline{f_{em11}}$	$\overline{f_{em12}}$	$\overline{f_{em13}}$
$\overline{f_{e2}}$	$\overline{f_{em21}}$	$\overline{f_{em22}}$	$\overline{f_{em23}}$
$\overline{f_{e3}}$	$\overline{f_{em31}}$	$\overline{f_{em32}}$	$\overline{f_{em33}}$

In total there are 15 types of hybrid actuations consisting of independent components. Testing all these experimentally is not an easy task so for the purpose of this study we would like to select only some of them. For this we would like to study each independent actuation and based on the results we will consider implementing an actuator that will have a large actuation domain that will provide high precision positioning.

IV. Experiments with standard actuators

First actuator studied was a PZT disk. Studies show that PZT is one of the best piezoelectric actuators in terms of displacement per unit voltage so in this paper it will be used as a comparison standard. For next experiments, including this one, all the displacements are measured using an interferometer designed for measuring deformation with a precision up to 1nm (Figure 2).

1 - laser head placed on an adjustable tripod.
2 - linear interferometer with attached linear retroreflector.
3 - two linear retroreflectors.
4 - special power electrodes.
5 - insulating foil.
6 - power cable.
7 - the sample (PZT disk) to be measured.
8 - laser beam generated by laser head.
9 - the laser beam reflected from the linear; retroreflector attached to the interferometer.
9 - the laser beam reflected from the linear retroreflector placed on the sample.

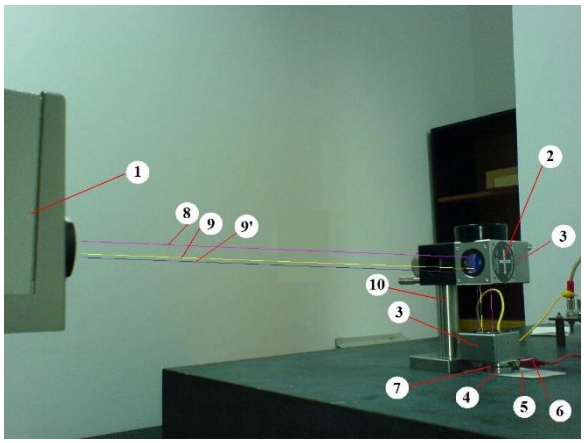

Figure 2. Interferometer with nanometric precision used to measure small displacements of actuators

Measurements were made for voltages in the interval 0-50V and the displacement - voltage graph was plotted:

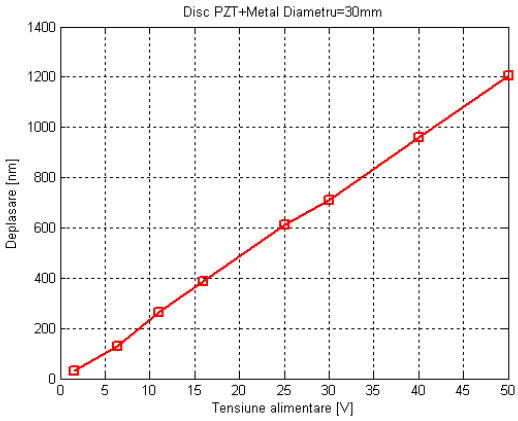

Figure 3. Displacement-voltage graph for the PZT piezoelectric actuator

From this graph we see that the dependence is linear. The displacement reaches a value of 1 micrometre for a voltage of 42V.

The approximate slope for the line that would fit the data from this graph is about 0.0244 μm/V.

We also tested some other materials such as an elastomer. We studied the behaviour of this material in commutation regime at 475V so that we can measure more properties such as the time of response.

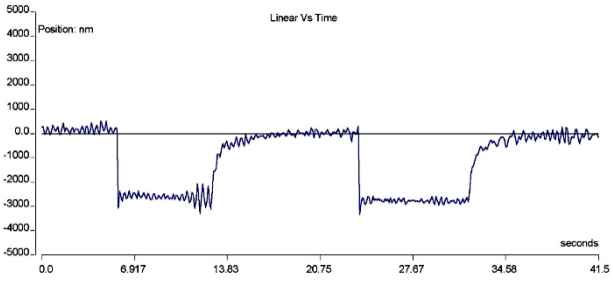

Figure 4. Displacement/time for Elastomer EH1 in commutation regime at 475V

First, we notice the displacement is negative so that means that the material contracts under the influence of the electric field. Also, we notice the response time is almost negligible. The maximum displacement is about 2700 nm and the time of discharge is about 3.64s.

For comparison, Figure 5 shows some polarization-depolarization cycles for the collagen PE3 membrane:

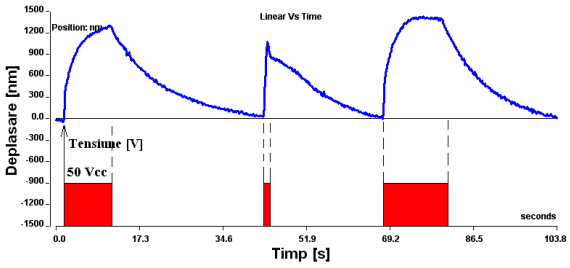

Figure 5. Charge-discharge cycles for the Collagen PE3 membrane

The maximum displacement reached is about 1.4 μm. The polarization and depolarisation duration are about 5.77 s and 20.18s respectively. Both responses are way slower than those of the EH1 elastomer.

In this paper we are mainly interested in the displacement-voltage dependence of each material, but for some applications, things like the polarization or depolarization time might also be an important criterion.

In similar experiments with different materials the displacement for certain voltages was measured and all relevant measurements were summed into the table below:

Table 4. Results of applying different voltages to some materials that exhibit piezoelectric and electrostrictive properties

Type of membrane	Collagen PE4	Collagen PE3	Elastomer EH1(HTV40)
Voltage(V)	30	50	475
Displacement (μm)	0.5	1.4	2.7

Elastomer EH6 (HTV40+20% pyrites)	Polymeric 5H with 20% pyrites	Polyamide with 10% BaO+TiO2	Quartz with 9% Ge
475	10	66	480
3.3	0.4	0.07	0.04

The best displacement to voltage ratio is obtained for the polymeric with 20% pyrites, but this material can be used only for low voltage applications since its breakdown voltage is low. The collagen membranes also give promising results and may have. Quartz has applications in devices involving the direct piezoelectric effect, since it can generate high voltages for small displacements.

From this table we found out that the following combinations may give good results:

- electromagnetic actuator combined with a piezoelectric actuator (PZT or collagen membrane),
- PZT actuator combined with the Polyamide.

These hybrid actuators have two operating modes: the brute mode which executes rough displacements which accounts for the rough positioning and the fine mode which executes small displacements accounting for the precise positioning stage. This way the above actuators can provide precise positioning for different domains.

V. Testing of electromagnetic-piezoelectric hybrid actuator

For testing the predictions above we built a hybrid actuator consisting of a piezoelectric actuator and an electromagnetic actuator, the setup used is shown in the figure below:

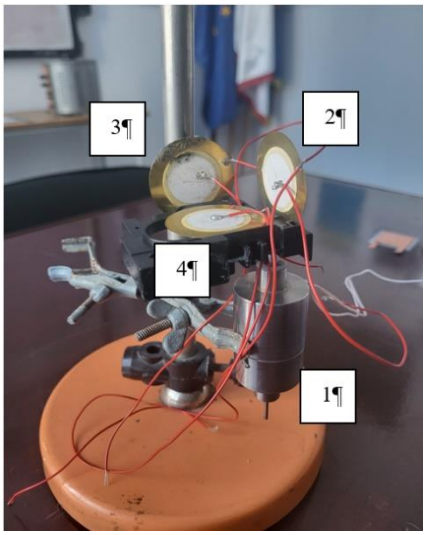

Figure 6. The setup of the hybrid actuator

The actuator designated with number 1 is the electromagnetic actuator and the others designated with 2,3 and 4 are piezoelectric actuators, each controlling one axis. In this setup we have one piezoelectric actuator for each axis, but since we are concerned with the behaviour of the hybrid actuator we will focus mainly on the vertical axis.

For each component of this actuator parameters were measured independently and the results are presented in the tables below:

Table 5. Measurements for the electromagnetic actuator

F[cN]	d[mm]	U[V]	I[A]
21	10,16	5	1,91
28	12,15	10	2,8
31	16,18	20	3
33	21,10	30	3,2

Table 6. Measurements for the piezoelectric actuator

U[V]	d[µm]	F[mN]
1	0,05	3
3	1	5
5	2,1	5,8
8	3,4	6,3
10	4,7	7,5

The dependence of displacement with respect to voltage were plotted on the graphs below:

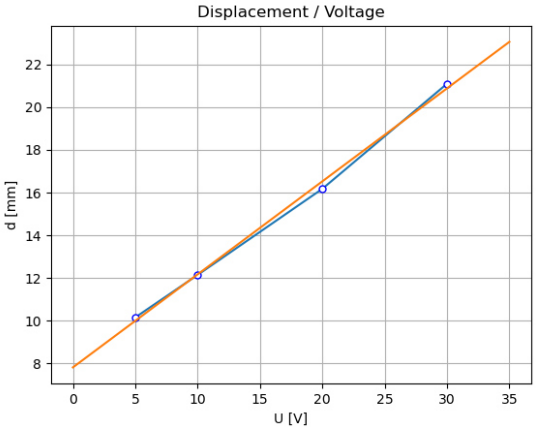

Figure 7. The displacement-voltage dependence for the electromagnetic actuator. The blue line connects the points and the orange one represents the best fit for the data

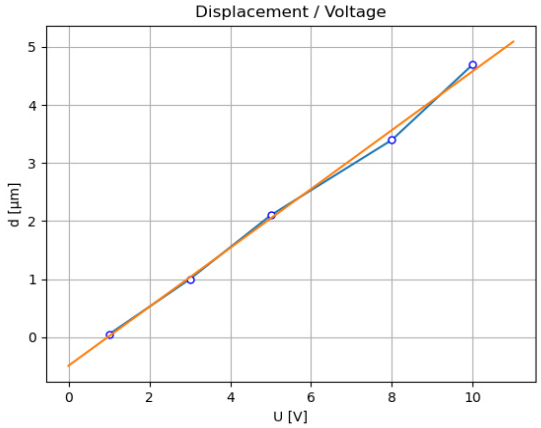

Figure 8. The displacement-voltage dependence for the piezoelectric actuator. The blue line connects the points and the orange one represents the best fit for the data

The orange line represents the line of best fit for the blue empty circles which represent the data collected experimentally for each actuator. For the electromagnetic actuator we have an intercept of 7.822mm and a slope of 0,4354 mm/V. For the piezoelectric actuator we have an intercept of -0.4906 µm and a slope of 0,5075 µm/V.

The reason why the intercept is not zero for the piezoelectric actuator is that the retroreflector of the interferometer used to measure the displacement has a mass that is initially compressing the actuator. This leads to an initial deformation.

Both actuators are controlled by different voltage sources. Considering that the voltage applied to each element can be controlled with a precision of 0.2V this would give us a precision of about 0.1mm for the electromagnetic actuator and up to 0.1µm for the piezoelectric actuator.

The piezoelectric actuator reaches a deformation of 0.1mm for a voltage of about 200V.

VI. Testing the PZT-elastomeric actuator

The PZT-elastomeric actuator has the structure shown in Figure 9:

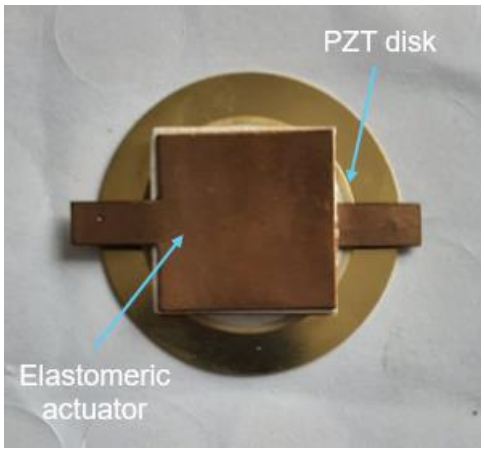

Figure 9. The setup of the hybrid PZT-elastomeric actuator

Our setup is simple, consisting of the two films sandwiched between two copper electrodes each. For each component of this actuator parameters were measured independently and the results are presented in the tables below:

Table 7. Measurements for the PZT actuator

U[V]	d[µm]	F[mN]
3,7	2	2,8
5	2,6	6
8	3,7	7,1
10	4,7	7,5

Table 8. Measurements for the elastomer

U[V]	d[µm]	F[mN]
60	0,4	1,8
80	0,9	2,2
100	1,6	3,0
110	1,9	4,2

The dependence of displacement with respect to voltage were plotted on the graphs below:

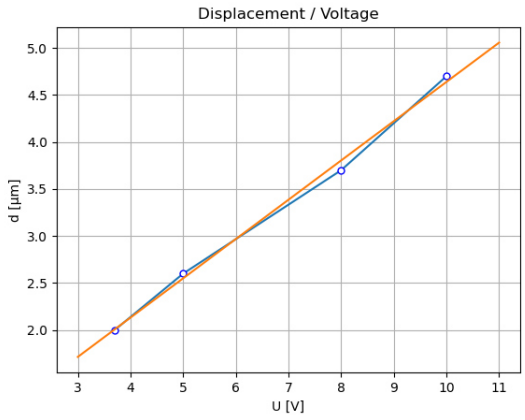

Figure 10. Graph with the data collected for the PZT actuator fitted by the orange line

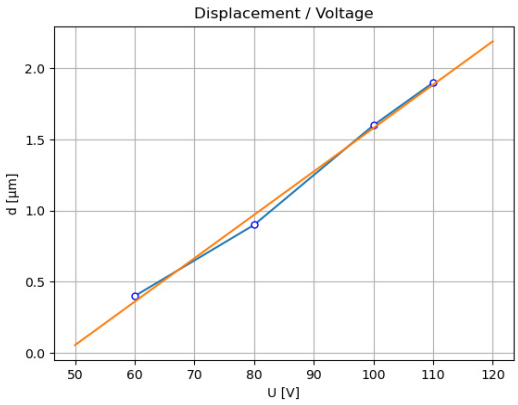

Figure 11. Graph with the data collected for the elastomeric actuator fitted by the orange line

For the PZT actuator we obtained a slope of about 0.418 µm/V and for the elastomeric actuator the slope is 30.5nm/V. The intercepts are nonzero, but they do not carry any physical meaning, as these are only a consequence of initial testing conditions. Both actuators should be operated independently. The power sources don't need to provide more than 10V for the actuator to work properly.

VII. Conclusions

We developed two devices that can be used in two stages to obtain precise positioning on different domains:

The electromagnetic - PZT actuator
Electromagnet - 0.4354mm/V
Piezoelectric PZT - 0.5075µm/V
and
The PZT - elastomeric actuator
PZT actuator - 0.418µm/V
Elastomeric membrane - 30.5nm/V

Both actuators fulfil the purpose for which they were built. These devices can provide a large actuation domain and high precision. Other papers propose actuators that are either unable to provide a great precision or they require a high voltage to obtain larger displacements. Our actuators perfectly combine the two through the twostep position method mentioned above. Nevertheless, these actuators are still some rough examples of the concept. To implement them in an actual experimental setup or other applications, further modifications such as miniaturization and fine-tuning of the device need to be performed.

VIII. Acknowledgment

The author acknowledges the contribution of PhD Mircea IGNAT for the guidance he has given during the development of the theme. Also, the author would like to thank the National Institute for Research and Development in Electrical Engineering ICPE-CA (INCDIE ICPE-CA) Bucharest for providing the necessary equipment and materials for this study.

IX. Bibliographic References

[1] IGNAT Mircea, "Theoretical aspects on ponderomotive forces", Bulletin of Micro and Nanoelectrotechnologies, June 2022, vol. XI, no. 3 – 4
[2] Daniel Kuang-Chen Liu, James Friend, Leslie Yeo, "A brief review of actuation at the micro-scale using electrostatics, electromagnetics and piezoelectric ultrasonics", Acoustical Science and Technology, 2010
[3] Kenji Uchino, "Introduction to Piezoelectric Actuators and Transducers", International Center for Actuators and Transducers, Penn State University, PA 16802
[4] Alison B. Flatau, Marcelo J. Dapino and Frederick T. Calkins, "On Magnetostrictive Transducer Applications", Materials for Smart Systems III, Materials Research Society Symposium Proceedings Volume 604
[5] Ignat Mircea, Amza Gheorghe, Hărăguță I. Cristinel, "Actuatori electromecanici neconvenționali", Editura Electra, București, 2002

IX. Authors' Biographies

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