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Editorial: Connecting Health and Innovation for the Biomedical Sciences' Future

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As part of the 4th Rencontre Biomédicale (RMB) of the Société Marocaine Biomédicale (SMB), which took place in Marrakech from February 20 to 22, 2025, we are pleased to present the inaugural issue of the Moroccan Journal of Health and Innovation (MJHI). This initiative is the result of the rich scientific momentum of the 3rd International Conference on Biomedical Engineering and Science (ICBES).

This publication was founded with the specific goal of giving high-impact, multidisciplinary research a platform that connects public health goals with biomedical innovation. Through collecting contributions from the fields of engineering, medicine, and digital health, MJHI seeks to showcase innovations that have the potential to revolutionize healthcare systems, especially in situations where sustainability, adaptability, and accessibility are crucial.

Rethinking Cancer Care Safety

This issue's introductory article tackles a critical oncology issue: how to provide radiation therapy effectively while lowering radiation risks. The study examines all-encompassing radiation protection measures, placing special emphasis on the integration of interprofessional collaboration, technical calibration, and quality assurance. By doing this, it makes a significant contribution to enhancing staff safety and patient outcomes.

Applying 3D Printing for Customized Rehabilitation

Our second article looks at the expanding use of 3D additive printing in the creation of prostheses and orthotics for the upper limbs. This technology is a paradigm shift in rehabilitation because it enables high levels of personalization, making assistive devices more accurate, accessible, and reasonably priced. Along with showcasing recent developments, the paper considers the difficulties that will arise in scaling up these breakthroughs in the future.

The MorWAK System for Transportable Kidney Care

Chronic kidney disease is still a major global health concern, particularly in underdeveloped areas. In order to facilitate out-of-hospital renal care, the third contribution introduces the MorWAK portable ultrafiltration device, a potential option that combines sophisticated membrane filtration with clever design. MorWAK's adaptable and modular design has the

potential to revolutionize the way dialysis is provided to vulnerable, rural, or mobile patient groups.

Breaking the Silos: Moroccan Healthcare Interoperability

The fourth study examines the effects of inadequate interoperability within the Moroccan health system, shifting the focus to systemic issues. By using a mixed-methods approach, it captures the experiences of both patients and professionals while quantifying delays, medical errors, and redundancies. These results highlight how urgently integrated digital infrastructures are needed to increase care continuity, fairness, and efficiency.

AI's Role in Smart Wearables for Cardiac Care

The incorporation of artificial intelligence into wearable cardiac monitoring devices is examined in the last article. These solutions provide better follow-up for patients with cardiovascular problems and early detection of arrhythmias by utilizing real-time processing and machine learning algorithms. The study opens the door for responsible and scalable adoption by posing ethical and regulatory issues in addition to its technical accomplishments.

A Visionary Journal

MJHI sets an atmosphere for what we believe will be a long-standing platform for significant research in biomedical innovation with these five groundbreaking contributions. In addition to publishing top-notch scientific research, we hope to promote communication among engineers, physicians, professors, researchers, legislators, students, and innovators who are all dedicated to rethinking health systems for the future.

The writers, reviewers, and conference attendees who have contributed to this first issue are deeply appreciated. May this journal encourage fresh partnerships, audacious concepts, and significant solutions—in Morocco, the surrounding area, and the global community.

Pr. Dr. Hicham CHATOUI

Editor-in-Chief & Publication Director

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Feasibility of ai-driven wearables for cardiac monitoring: a path toward personalized cardiac care

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Abstract: CVDs are the leading cause of death worldwide, accounting for approximately 17.9 million deaths annually. Management is effectively performed with continuous real-time monitoring for early detection and customized care. This paper discusses the feasibility of using AI in portable cardiac monitoring devices to overcome traditional tools such as ECGs and Holter monitors, which have always been confined to hospitals. The novelty of this work is the exploitation of AI algorithms such as machine learning and deep learning models to enhance diagnostic capabilities for wearable devices. It also presents a proposed methodology that outlines state-of-the-art wearable devices, complemented by an analysis of sensor technologies such as ECG and PPG. Real-time AI processing frameworks, including those for edge computing, are reviewed to mitigate challenges such as noisy signals or limited battery lifetimes. Ethical considerations concerning data privacy and algorithmic fairness ensure that these systems are responsibly deployed. Preliminary conclusions are that AI on wearable devices empowers cardiac care with the early detection of arrhythmias, allows for the best performance of pacemakers, and reduces hospital readmissions. This research also advances a more active strategy for integrating wearable devices with AI for the next generation in proactive and personalized cardiac care. Future work would involve the validation of those findings with clinical trials and look into broader applications in multimorbid conditions.

Keywords: Cardiovascular diseases (CVDs), Artificial intelligence (AI), Wearable technology, Cardiac monitoring, Personalized healthcare.

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1. Introduction

1.1. Background and Motivation

CVDs are the leading cause of death worldwide, accounting for almost 17.9 million deaths annually (WHO, 2023). Despite all the advances in medical technology, early detection and continuous monitoring still remain one of the biggest challenges of outpatient and home-based care. Early detection of cardiac abnormalities like arrhythmias, myocardial ischemia, and heart failure deterioration is of vital importance for timely intervention, reduction in hospital readmission, and improvement in patient outcomes (Lee et al., 2022).

Until today, 12-lead electrocardiograms and Holter monitors have been the most common diagnostic tests for cardiac disorders. Both are extremely limited. Hospital-based ECGs yield only snapshots of brief moments in the activity of the heart, thus usually missing transient arrhythmias or ischemic events. These monitoring systems also restrain mobility, requiring that patients visit clinical settings, and thereby render real-world tracking of cardiac function difficult. Even ambulatory solutions, such as Holter monitors, provide only intermittent monitoring, which is usually performed in spans of 24 to 48 hours. This span may be too short a time to detect less frequent cardiac abnormalities. Most such devices are bulky and uncomfortable to wear, therefore resulting in very poor patient compliance, which hinders their ability to perform as long-term monitors of cardiac patients (Kim et al., 2023).

Wearable biomedical devices bring a paradigm shift in providing continuous, non-invasive cardiac monitoring outside clinical settings. These wearable devices incorporate miniaturized biosensors that are capable of measuring electrocardiography, photoplethysmography, seismocardiography, and ballistocardiography, thus allowing real-time remote monitoring of cardiac activity without hindrance in the mobility of the patients (Kim et al., 2023). Unlike typical hospital-based systems, wearable cardiac monitors can continuously track cardiac rhythm and hence allow the identification of abnormalities well in advance and the administering of personalized health interventions.

Commercially available cardiac monitoring wearables have already shown clinical utility. The Apple Watch and Fitbit, with their PPG-based heart rate monitoring, have immense potential for the detection of AFib-a major risk factor for stroke-while AliveCor's KardiaMobile has received FDA clearance for the detection of arrhythmias using a single-lead ECG. These point to the very fact that wearable cardiac monitoring is going beyond fitness tracking into medical-grade, AI-enhanced diagnostics (Perez et al., 2019).

In essence, integration with AI and ML will further amplify the diagnosis probability of a wearable cardiac monitor. Algorithms of AI manage volumes of real-time physiological data with high precision for the identification of abnormal heart patterns. Deep learning models, including CNNs and RNNs, further empower these wearable systems in the classification of cardiac rhythms and detection of anomalies, while some are even able to predict impending cardiovascular events before their symptomatic manifestation could occur (Nguyen et al., 2024). Contrary to the traditional diagnostic techniques that rely on fixed threshold values, wearables driven by AI include a personalized approach while adapting to the individual data of patients over time.

Despite the enormous potential, there are a couple of technical challenges that AI-driven wearable cardiac monitors face in striving to ensure accuracy, efficiency, and reliability. Signal quality and motion artifacts rank among the principal challenges. As wearable sensors are naturally exposed to movement and environmental noise, there could be some kind of distortion in ECG and PPG signals, reducing diagnostic accuracy. Advanced noise-filtering algorithms and novel AI-based signal enhancement techniques are under active development, which advances real-time cardiac analysis by reducing motion-induced errors (Wu et al., 2023).

Another critical challenge for wearable cardiac monitors is to ensure computational and energy efficiency. Whereas AI-based models are computationally intensive, wearable devices have very limited processing capabilities due to their small form factor and restricted battery life. Optimized AI models developed using techniques such as TinyML, knowledge distillation, and quantization enable real-time cardiac monitoring with minimal energy consumption (Williams et al., 2023; Chen et al., 2025). New energy-harvesting technologies, such as solar-powered wearables, are also under study to enable even longer battery lifetimes and hence extended continuous monitoring capabilities (HHS, 2024).

The most important non-technical consideration for mass acceptance is the issue of privacy and security associated with AI-enabled wearables for health monitoring. Because the health of the heart concerns sensitive personal health information, the security of data and protection of privacy become extremely important. AI-powered monitoring systems have to be designed under the strict data protection regulations of HIPAA in the U.S. and the General Data Protection Regulation (GDPR) of the EU (European Commission, 2021). Federated learning is a new class of AI that enables on-device training of AI models without transferring the raw patient data to cloud servers, significantly enhancing privacy and reducing the possibility of data breaches (European Commission, 2021).

Future generations of wearable cardiac monitors powered by AI will integrate multi-modal sensor

fusion, rich AI analytics, and hybrid cloud-edge computing architectures into fully automated real-time monitoring solutions. Hybrid AI models will also allow low-power, real-time inference on wearable devices, using cloud computing for more advanced predictive analytics. Other new developments also include smart pacemakers and AI-driven implantable cardiac devices for adaptive, real-time responses to cardiovascular conditions, improving cardiac disease management and patient survival rates. This wearable cardiac monitor will also be part of a smart home ecosystem in which IoT-based devices communicate to create a holistic health monitoring environment (Moshawrab et al., 2023; Dong et al., 2024).

1.2. Objective and scope

This study will perform a theoretical feasibility analysis of wearable cardiac monitors using AI, focusing on the following four significant aspects:

- Integration of multimodal sensors: ECG, PPG and SCG.
- Computational feasibility with respect to real-time AI processing.
- Energy efficiency in relation to energy consumption constraints.

This is not an experimental study; no prototype has been developed and no clinical trials have been carried out. However, the various technological and practical obstacles that exist in deploying an AI-powered cardiac monitoring system are considered.

2. Feasibility of Wearable Sensor Technologies

Wearable cardiac monitoring devices generally use different sensor technologies, which provide the actual acquisition of physiological and biomechanical signals. In fact, each type of sensor technology has advantages facing many challenges, including those dealing with accuracy and power consumption, while ensuring efficiency during processing. In essence, their usage ideally should ensure low energy consumption while guaranteeing high signal fidelity even at extreme intensities of motion, which would be expected from reliable cardiac monitoring.

2.1. Electrocardiography (ECG)

The ECG is still considered the gold standard for monitoring arrhythmias, heart rate variability, and myocardial ischemia. The ECG sensors measure the electrical activity of the heart through electrodes attached to the skin that record changes in voltage as the heart contracts and relaxes.

Benefits will be ECG that will be highly diagnostic, with great accuracy in detecting arrhythmias,

clinical validation in both hospital and portable applications, and the real-time, continuous monitoring of patients in acute situations. PECG usual challenges include motion artefacts, which make signals less reliable in portable format; it requires a bigger power supply for continuous operations and electrode placement affects signal quality.

Recent development of flexible ECG sensors dramatically improves the quality of signal acquisition, reducing noise introduced by subject movement and allowing higher portability. The implementation of new dry electrode technologies free from conductive gel is yet another effort aimed at improving the patient's comfort, thus extending the portability time (Kim et al., 2023).

2.2. Photoplethysmography (PPG)

Because this technology is by definition non-invasive and low power, it finds many applications in consumer smart wearables and fitness trackers. Light sources within PPG sensors produce infrared or green light, the absorption of which changes with each heartbeat, reflecting changes in blood volume.

Advantages of PPG are that it consumes low power and is thus fit for battery-powered wearables. It is also non-invasive, with no need to touch skin directly, unlike the electrodes in ECG. The small size and low cost hence make it very applicable in many commercial wearable devices.

However, some challenges still exist : It is prone to motion artefacts and noise, hence its accuracy can degrade. Low HRV accuracy results in a non-reliable diagnosis. Poor performances on subjects with darker skin brings up a bunch of bias related issues.

Regarding the enhancement in PPG, AI-based de-noising algorithms and multi-wavelength techniques in literature put in place by different researchers compensate for variations in skin tone and motion artefacts compensation (Wu et al., 2023).

2.3. Seismocardiography (SCG) and ballistocardiography (BCG)

There are two presently used methods to measure cardiac mechanical activity: Seismocardiography and ballistocardiography. Both these methods offer more additional information on cardiac performance that cannot be provided by either ECG or PPG.

SCG records chest wall vibrations produced by myocardial contractions. It gives information about contractility and the ejection fraction of the cardiac cycle.

It provides the identification of micro-vibrations in the body resulting from cardiac output and ejection of blood into the circulation. So many advantages, but just to name a few: SCG and BCG have better overall system reliability by complementation with ECG and PPG. They offer a noninvasive way to estimate cardiac contractility. They can also be incorporated into wearable patches or smart clothes.

Their major drawbacks are as follows: Sensor placement is critical with regard to the accuracy of the results. SCG-BCG signals are of relatively low resolution compared to ECG methods. Signal interpretation is very resource-consuming, considering computational resources.

Despite all these issues, SCG-BCG fusion with AI-based multimodal cardiac monitoring becomes a promising direction of research (Moshawrab et al., 2023; Dong et al., 2024).

2.4. Multimodal sensor fusion

In this context, the ECG, PPG and SCG offer multimodal integration of the sensor fusion for multi-fold enhancement in the reliability and precision of these three sensors. Besides that, the multi-sensor technique so devised reduces each kind of individual inconvenience while providing a very powerful cardiac anomaly investigation system.

Example: the ECG is very accurate for monitoring the electrical activity of the heart, while being very sensitive to the movement artefact itself; on the other hand, the PPG is not very powerful and is easy to wear, but its diagnostic value is low in terms of heart rate analysis; while the SCG provides mechanical information and improves the analysis of contractility.

However, multimodal integration leads to computational complexity and power requirements, which calls for hardware and software architectures optimised for real-time processing (Zhou et al., 2023; John et al., 2024). Edge computing and AI-enhanced signal processing solutions are being developed to address these challenges.

The following chart compares ECG, PPG and SCG in terms of accuracy, energy efficiency and robustness to motion to provide a better comparison of the strengths and weaknesses of each sensor type.

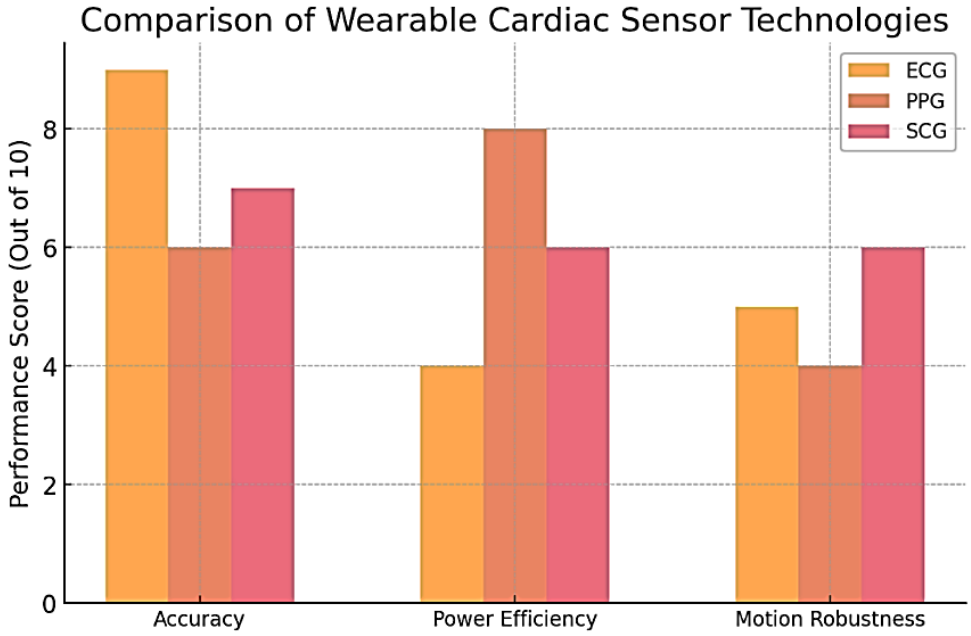

Figure 1. Comparison of Wearable Cardiac Sensor Technologies

This figure represents the fact that there is a trade-off in the sensor types, and the optimum needs to hybridize them into a balancing act among accuracy, power consumption, and robustness toward motion artifacts. While ECG has excellent diagnostic precision, it is power-consuming and sensitive to motion. PPG is energy-efficient but lacks real-world accuracy. SCG is useful for mechanical insight but involves precise sensor placement.

Wearable cardiac monitors can achieve maximum reliability and diagnostic performance using multi-modal sensor fusion in the face of a variety of individual sensor limitations. The forthcoming next generation of wearable AI-enabled personalized health will be integrated.

3. AI-Based Signal Processing in Cardiac Monitoring

The development of AI-driven wearables for cardiac monitoring should go hand in hand with sophisticated signal processing techniques to provide real-time, precise detection of anomalies in the heart, which in turn would mean a balance between energy efficiency and computational constraints. Traditional cloud-based processing introduces latency, raises privacy concerns, and dependency on network connectivity. In its place, edge AI has started to emerge as the favored choice where on-device AI inference will result in faster and more secure diagnosis without transferring sensitive data to external servers.

It is challenging to realize this in light of memory, computational power, and energy requirements

imposed by deep learning models. Wearables with suitable architecture in AI together with techniques of model optimization will meet the challenges of high diagnostic accuracy at power constraints.

3.1. Wearable AI Architectures

Therefore, sophisticated techniques in signal processing have developed to become an integral ingredient of trade-offs involving energy efficiency, computation constraints, and real-time anomaly detection of the heart. Most of all, it was limited by latency and issues related to data privacy, given that cloud-based processing is highly dependent on connectivity. Edge AI has hence grown as one of the preferable ways where inference of on-device AI may speed up and thus secure the diagnoses without needing the transmission of sensitive information to servers sitting at distant locations.

Deep learning models, with huge demands in memory, computational power, and energy, cannot be directly deployed on wearable devices. Efficient AI architectures and model optimization techniques have been employed for making a wearable device operate under power constraints with high diagnostic accuracy (Nguyen et al., 2024).

Convolutional Neural Networks for ECG Classification

The wide applications of CNNs in ECG waveform classification include proficiency in extracting spatial patterns and detecting abnormalities such as AFib, ventricular tachycardia, and bradycardia. Several CNN-based models, trained on vast amounts of ECG datasets, were then deployed into FDA-approved wearable devices owing to their high diagnostic precisions (Nguyen et al., 2024).

CNN benefits in ECG classification: High accuracy of detection of cardiac abnormalities, feature extraction is automatic, with not much manual analysis required. Suitable for real-world wearable deployment.

Challenges with CNN: Though possible, some reduction of the computational load can be achieved through optimization.

Hybrid CNN-LSTM Model for Time-Series Analysis

Although performing well, CNNs cannot catch long-run temporal dependencies in cardiac signals. Hence, RNN variant-LSTM-comes out to be ideal for applications dealing with such sequential time-series data. Therefore, the study of heart rate variability and anomaly detection within become of extensive usage. The hybrid model employs a combination of both: CNN for feature extraction from

the ECG waveform and LSTM for analyzing the time-dependent trends in HRV.

It benefits from this hybrid model in enhancing AI-based cardiac monitoring, especially for diagnosis related to heart failure, ischemia, and the progression of arrhythmias (Nguyen et al., 2024).

Model Optimization on Wearable Devices

Deep learning models, although very memory-intensive and computationally expensive, need optimization on these resource-constrained wearable devices. The major techniques include:

- Knowledge Distillation: The technique of knowledge transfer from a big, complex AI model into a small, efficient one reduces computational demand.
- Quantization: A good example is reducing 32-bit floating-point models to 8-bit integer models, which decreases memory usage by 75% while maintaining accuracy (Nguyen et al., 2024).
- Pruning: This removes unnecessary neural connections, hence decreasing model complexity without major loss in accuracy.

It could be inferred that all these methods of optimization will allow efficiency in ECG signal processing with battery life in AI-powered wearables while ensuring high diagnostic performance.

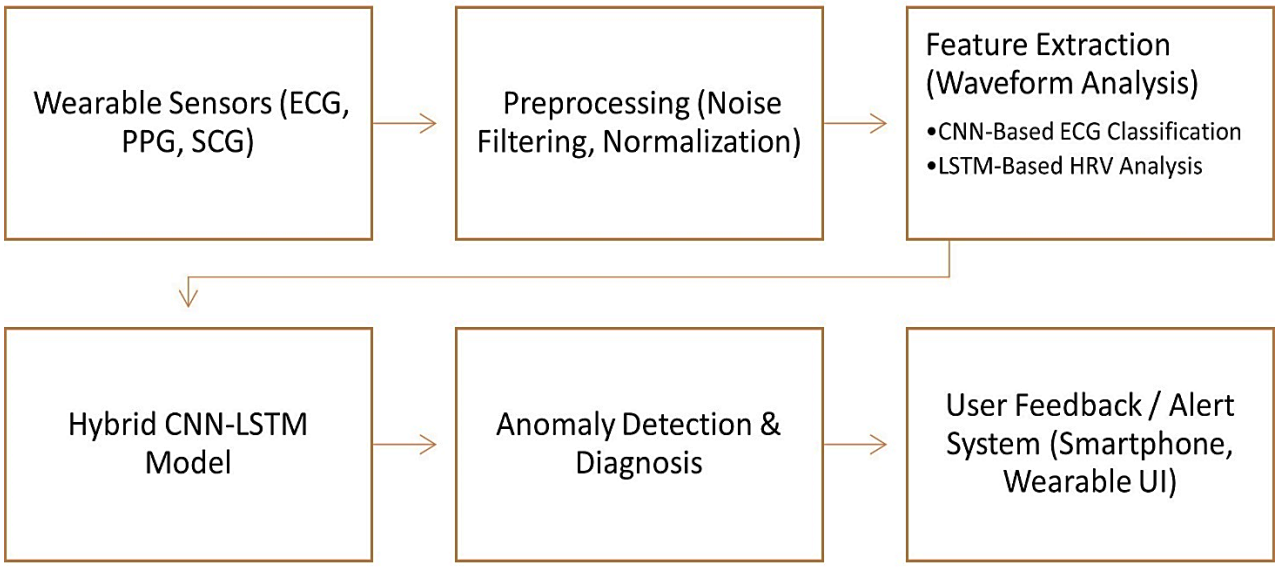

Figure 2. AI Processing In Wearable Cardiac Monitoring

The following is a summary of the flowchart above for the sequential AI processing pipeline in wearable cardiac monitoring systems:

1. Wearable sensors comprising ECG, PPG, and SCG capture physiological signals.
2. Pre-processing operations filter noise from the signal and normalize it, hence preparing it for superior processing by the artificial intelligence system.
3. Feature extraction that would, in turn, bring out some critical waveform patterns.
4. The CNN-based classifiers classify the signals of ECG and detect any arrhythmia.
5. LSTM analyzes temporal variations of heart rate variability.
6. A hybrid CNN-LSTM model fuses spatial and temporal features for accurate anomaly detection.
7. When an anomaly is detected, diagnostic alerts are triggered, hence allowing for real-time intervention.
8. Feedback is provided instantly to the user via a smartphone or wearable interface.

This AI-based approach provides fast real-time cardiac monitoring, improving early diagnosis, patient engagement, and personalized healthcare.

3.2. Federated Learning for Preserving Privacy

One huge challenge in AI-powered monitoring is how to assure data privacy for the patient. Traditional cloud AI involves continuous data uploading, raising several regulatory and data ownership issues apart from other security concerns. Thus, the newly developed architecture, known as federated learning, enables model training on devices where patients maintain their private data (Williams et al., 2023).

How Federated Learning Works:

1. Each wearable device trains an AI model locally with patient-specific ECG and PPG data.
2. Instead of raw data transmission to the central server, model updates are transmitted.
3. The global AI model, on a central server, is refined by aggregating updates from multiple devices.
4. Return the improved AI model from wearables in order to boost the accuracy while not

exposing any patient data (Williams et al., 2023).

Some key takeaways the principals can have from Federated Learning in wearables are: Data privacy is guaranteed since no raw patient data is being sent out. It reduces bandwidth and power consumption, hence more efficient. Learns from decentralized data sources increasing model accuracy across diverse populations. Complies with regulations (HIPAA, GDPR) and thus enables ethical AI deployment (HHS, 2024), (European Commission, 2021).

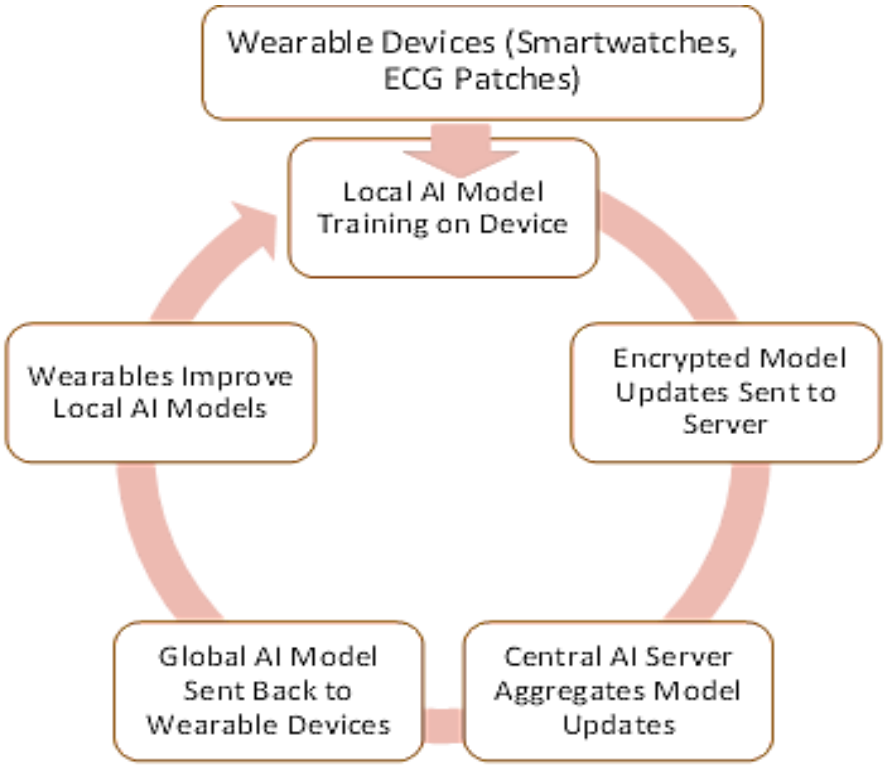

Figure 3. Federated Learning In Wearable Cardiac Monitoring

The above flowchart represents how FL works in wearable cardiac AI systems:

1. Wearable devices themselves, like smartwatches and ECG patches, locally train an AI model based on patient-specific ECG and PPG data.
2. Instead of sharing raw data, encrypted model updates are sent to a central AI server.
3. The central server aggregates updates arriving from multiple devices, refining the global AI model.
4. The improved global model is broadcast to the participating devices in order to improve the local AI models further.

5. Every device keeps on training on freshly added data and, in parallel, continuously improving onboard AI performance.

What this means is that there is no leakage of information outside the device; hence, security and compliance are inherently improved, further optimizing AI diagnostics.

Cardiac monitoring by next-generation wearables will be entirely dependent on AI-enabled signal processing. Hybrid CNN-LSTM architecture, on-device model optimizations, and even privacy-patient data-based federated learning are the powerful building blocks to drive AI forward in wearables. That would open up pathways to real-time, personalized, proactive cardiac care.

4. Power Consumption and Energy Efficiency in AI-Driven Wearable Cardiac Monitoring

Continuous operation of AI-driven wearable cardiac monitors requires minimal power consumption to ensure long battery life and continuous monitoring. As wearable devices use small rechargeable batteries, it is essential to reduce power consumption so that they can be used in the real world (Gautam et al., 2022; Zheng et al., 2025).

4.1. Power Consumption Analysis

The total power consumption of an AI-driven wearable cardiac monitoring system is influenced by three primary components:

Table 1. Power Consumption Analysis of AI-Driven Wearable Cardiac Monitoring Components

Component	Power Consumption (mW)
ECG Sensor (Continuous Monitoring)	2.1 mW
Microcontroller (MCU) Running AI Inference	3.2 mW
Bluetooth Low Energy (BLE) Transmission	1.5 mW
Total Estimated Power Draw	**6.8 mW**

- ECG sensor: 2.1 mW. ECG electrodes require continuous acquisition of the electrical signal that is part of the baseline consumption.
- MCU running AI inference: 3.2 mW. AI-driven classification and HRV analysis require heavy computation; hence, this module is one of the highest power-consuming components.

- BLE transmission: 1.5 mW. Wireless communication is required for real-time monitoring; however, BLE data transmission still remains power-consuming.

Although 6.8 mW is a small value, considering long-term operation, a regular battery, for example, 40 mAh Li-Po, will be quickly depleted if no energy optimization strategies are implemented (Gautam et al., 2022; Zheng et al., 2025).

4.2. Energy Efficiency Optimization Strategies

To extend the battery life and make AI-powered wearables more sustainable, several optimization techniques are employed:

a.Power Reduction by Duty Cycling

Instead of continuous operation, sensors can be turned on periodically to avoid unnecessary power consumption.
ECG sensors can sample in intervals, such as every 5 seconds, rather than constantly, which already can cut energy consumption by as much as 40%.

Event-triggered monitoring: AI may detect irregular cardiac patterns before the full monitoring mode is turned on, further extending battery life.

b.TinyML for Efficient AI

• Tiny Machine Learning-TinyML-allows low-power AI processing directly on the MCU.
• Model quantization and knowledge distillation shrink AI model size by 75%, enabling more power-efficient real-time inference.
• Optimized neural network architectures, for example, MobileNet or Edge TPU models, reduce the computational overhead with no loss in accuracy.

c.Energy Harvesting for Self-Powered Wearables

• Wearable patches or smartwatches can be integrated with flexible photovoltaic cells. The cells yield up to 10 μW/cm² under indoor lighting conditions, increasing battery lifetime by 20%.
• Energy-harvesting TEGs are able to convert body heat into electrical energy continuously for supplementing power (Gautam et al., 2022; Zheng et al., 2025)

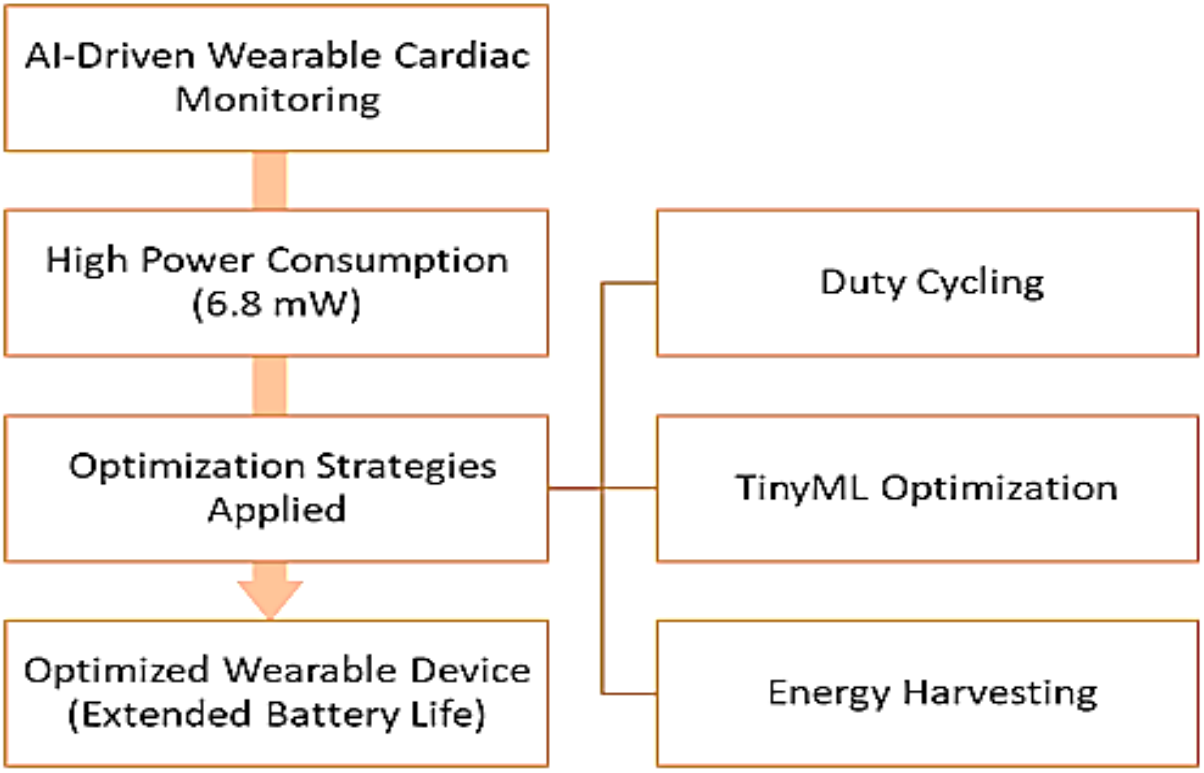

Figure 4. Power Optimization In Wearable AI Monitoring

The key power optimization techniques will enable a single charge to keep an AI-driven cardiac monitor running for much longer and thereby make it a more viable activity in practical medical applications.

Above is the flowchart that demonstrates how an AI-driven wearable cardiac monitor saves power:

1. AI-Driven Wearable Cardiac Monitoring: High, 6.8 mW, because the sensors operate constantly, along with AI inference and BLE transmission.

2. Application of optimization techniques leads to energy efficiency.

3. The following are three major power-saving techniques implemented:

- Duty Cycling: The activation of sensors is reduced, thus minimizing the wastage of energy on redundant usage.

- TinyML optimisation: This enables AI inference with low energy consumption, reducing the computational load.
- Energy harvesting: Energy production based on solar and body heat increases battery life.

These methods, once implemented, materialize a wearable device with optimized, extended battery life that may allow real-world wearability.

Power consumption analysis identifies ECG sensors, AI interference, and BLE transmission as major power-consuming components. With different optimization strategies in place, such as Duty Cycling, TinyML, and Energy Harvesting, it helps reduce the power usage in order to extend battery life. How energy efficiency can be achieved in AI-driven wearables.

5. Feasibility Analysis of AI-driven Wearable Cardiac Monitoring

Overall, the viability of AI-driven wearable heart monitors will be driven by sensor accuracy, processing capability, energy efficiency, connectivity, user experience and regulatory compliance. Although considerable progress has been made in AI-based signal processing, a number of technical, practical and regulatory challenges need to be addressed before widespread diffusion can take place. (Moshawrab et al., 2023; Dong et al., 2024).

This section considers each important component of the AI-powered wearable cardiac monitoring system in depth to analyze its advantages, challenges, and feasibility ratings in view of the current stage of development and their future potentials. Feasibility ratings ★ out of 5 are given to denote how ready a component is for deployment and also to show areas where further optimizations are needed.

The following feasibility breakdown will analyze respective strong points, some limitations, and technological gaps in the implementation of wearables with enhanced AI cardiac monitoring.

Feasibility Breakdown

Table 2. Feasibility Assessment of AI-Driven Wearable Cardiac Monitoring Components

Component	Advantages	Challenges	Feasibility Rating (★ out of 5)
Wearable Sensors (ECG, PPG, SCG)	Accurate monitoring; non-invasive.	Motion artifacts; limited resolution.	★★★★☆ (Multi-sensor fusion needed.)
Signal Processing & Edge AI	Real-time detection; reduced latency.	Computational constraints; requires model optimization.	★★★★☆ (Feasible with optimized AI.)
Wireless Transmission (BLE, Wi-Fi)	Low power consumption; widely used.	Data transmission drains battery; event-triggered strategies needed.	★★★★☆ (Optimized transmission required.)
Cloud/Server for Analysis	High computational power; long-term monitoring.	Privacy risks; latency issues.	★★★☆☆ (Hybrid cloud-edge needed.)
User Interface (Smartphone App)	Real-time user feedback; doctor monitoring.	Connectivity and compliance challenges.	★★★★★ (Already proven in industry.)
Regulatory & Privacy Compliance	Strong data protection laws in place.	Algorithmic bias; long regulatory approval process.	★★★☆☆ (Regulatory barriers remain.)

This feasibility assessment highlights the current readiness and limitations of each component of AI-driven cardiac wearable devices. While there have been significant advances in the core technologies of wearable sensors, AI-based signal processing and wireless communication, privacy, regulatory compliance and energy efficiency remain areas that require improvement to enable scalability for real-world adoption.

6.Conclusion

This work justifies the technical feasibility of integrating multimodal sensors with edge AI processing and AI-driven wearable cardiac monitoring based on the principle of federated learning. Advanced biosensors, real-time AI algorithms, and low-power processing techniques finally meet to bring about continuous, personalized cardiac monitoring with enhanced diagnostic accuracy, the possibility of early detection of arrhythmias, and proactive intervention strategies. In this way, the final results of the research will be minimized re-admission to hospitals, improved patient outcomes, and an important step toward remote healthcare.

However, besides these technological developments, several important challenges have to be resolved before this technology could see general clinical applications, which include:

- Sensor reliability
- Energy efficiency
- Wireless communication & data security
- Regulatory and ethical considerations

Wearable devices for cardiac monitoring using AI have the immense capability to bring in a paradigm change in personalized cardiac care. This AI-powered wearable device will connect powerfully amongst technology, medicine, and regulatory frameworks to make proactive cardiovascular disease management a possibility from mere diagnosis-based treatment to continuous home-based monitoring. Simultaneously, it empowers patients, reduces the healthcare burden, and hence improves overall cardiac health outcomes in the world.

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3D impression as an additive technology in upper limb orthotics and prosthetics: advancements, applications, and perspectives

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Abstract: 3D additive technology is revolutionizing the field of upper limb orthotic and prosthetic manufacturing, offering customized, efficient and cost-effective solutions. This article examines the evolution of the use of 3D printing in the design and manufacture of orthotics and prosthetic for the upper limb, highlighting its advantages over traditional methods. We explore the various applications of this technology, such as the creation of custom orthotics and prosthetic for patients with orthopedic, neurological or musculoskeletal disorders. In addition, we discuss current challenges and future opportunities in this field, particularly with regard to the accuracy, durability and accessibility of orthotics and prosthetic made by 3D printing. In conclusion, this article highlights the potential of 3D additive technology to improve the quality of life of patients requiring upper limb orthotics and prosthetic, while paving the way for new advances in rehabilitation and personalized treatment.

Keywords: 3D printing, additive technology, upper limb orthoses, upper limb prostheses, personalization, rehabilitation, cost-effectiveness, durability, accessibility.

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1. Introduction

People with upper limb deficiencies, whether congenital, accidental or due to degenerative diseases, face considerable challenges in their daily lives. These deficiencies affect not only functional mobility, but also patients' quality of life. Traditional solutions to treat these deficiencies rely mainly on orthoses and prostheses, which are essential for restoring upper limb function, supporting the joint or replacing a missing limb. However, to be effective, these devices must be perfectly adapted to each patient's specific anatomy and the particular needs associated with their pathology or condition. Customization is therefore a key aspect in the design of these devices, to ensure their long-term effectiveness and comfort of use (Gadhave et al., 2024).

Traditional methods used to manufacture these devices include molding, milling and laminating. Although these methods have been widely used for decades, they have several major limitations. Casting, for example, involves manual impression taking, which can be an invasive and uncomfortable procedure for the patient. Secondly, producing the prosthesis or orthosis from these impressions can be time-consuming and costly, with margins of error likely to affect the fit of the device. What's more, these methods do not allow adjustments to be made easily after initial manufacture, which can make it difficult to achieve the best solution for the patient, particularly in cases requiring frequent modifications (Farhan et al., 2021).

The emergence of 3D additive manufacturing technology, or 3D printing, has transformed the field of orthotics and prosthetics. This technology makes it possible to create medical devices with a high degree of customization, directly from digital models of the patient. Unlike traditional techniques, 3D printing offers unprecedented flexibility, enabling the production of customized prostheses in a matter of hours rather than weeks, while reducing the associated costs. Devices can be designed with extreme precision, taking into account the anatomical specifications of each patient, thanks to 3D scans obtained by computed tomography (CT) or magnetic resonance imaging (MRI). This approach overcomes the challenges associated with manual manufacturing, while guaranteeing devices that are more comfortable and better adapted to each patient's unique anatomy (Aimar et al., 2019).

What's more, the use of polymer and composite materials in 3D printing makes it possible to obtain devices that are not only lightweight, but also resistant and functional. The new materials used in this technology offer mechanical characteristics comparable to those of materials used in traditional methods, but with reduced production costs and considerably shorter lead times. What's more, 3D printing allows flexibility in the choice of materials, offering solutions that can be optimized according to the patient's specific needs, particularly in terms of strength, comfort and durability (Pal

et al., 2021).

One of the main advantages of 3D printing lies in its ability to offer truly customized solutions for each individual patient. By combining high-precision scanning technologies with computer-aided design (CAD) software, it is possible to create detailed 3D models of the affected area, and then tailor the design to the patient's functional, aesthetic and biomechanical needs. This contrasts with traditional methods, which can impose compromises in customization due to the rigidity of manufacturing processes (Dave et al., 2024). In addition, 3D printing enables rapid adjustments to be made to the prosthesis or orthosis model, without having to restart the entire manufacturing process. This minimizes waiting times and enables faster, more efficient patient care (Iftekar et al., 2024).Therefore, this technology has the ability to change the way prostheses and orthoses are made, as well as how they are to be perceived by patients and used by patients in accordance with such products. Improved fit and comfort of device are also received with almost absolute personalization in terms of satisfaction by patients, which can then move toward positive outcomes in the functional unchanging future. Further, 3D printing reduces the cost of production for orthoses and prostheses, thus providing many patients with better access to such medical devices, even in those areas where conventional modes of medical practice are limited (Roh et al., 2013)

The purpose of this article is to investigate the evolution of 3D printing in the design and manufacture of upper limb orthoses and prostheses and to demonstrate its advantages to previous traditional manufacturing methods. This article will also discuss challenges in the mass adoption of this technology, which include but are not limited to issues of accuracy, material durability and access in various clinical settings. Finally, we will see in future what might happen with this upcoming technology of 3D printing, including how it will change their rehabilitation and personalized treatments into increasingly affordable, speedier and better tailored solutions for specific patient needs.

2. 3D printing evolution in the manufacture of upper limb orthoses and prostheses

- Early applications of 3D printing in the medical field

3D printing was first introduced to the medical device field in the 1990s, but its adoption in the orthotics and prosthetics sector has intensified over the past decade. Initially used for the manufacture of surgical models and tools, it quickly found applications in the manufacture of prostheses, thanks to its ability to create custom parts from digital scans (Whitaker et al., 2014).

- Recent technological advances

Advances in 3D printing technologies have led to significant improvements in precision, speed and cost. The introduction of materials such as thermoplastics and carbon-fiber composites has enabled the creation of stronger, lighter and more durable devices (Pérez et al., 2020). In addition, the use of digital modeling enables devices to be customized with great precision, guaranteeing greater adaptability to patient needs.

- Clinical adoption of 3D printing

The integration of 3D printing into clinical practice has led to shorter manufacturing times for prosthetics and orthotics, improved fit quality and more suitable and accessible solutions for patients (Huang et al., 2013).

3. Process of Creating Customized 3D-Printed Upper Limb Orthotics and Prosthetics

Architectural, tailoring, and utility are among the most paramount keynotes, which are essentially specific in the processes of designing 3D printed orthotics and prosthetics for upper limbs (Xu et al., 2017; Oud et al., 2021):

1. Patient evaluation and imaging: This comprises a physical examination of the patient as well as the acquisition of highly detailed anatomical information via 3D scanning or another modality such as MRI or CT. This captures the unique body structures, resulting in a precise fit for the finished product.
2. A beautiful and useful design resulted from careful consideration of details such as joints and grips. Prototype 3D designs that precisely match a patient's anatomy are created from scanned data using modern CAD software.
3. Materials Selection: The appropriate materials that meet the specific needs of the patient with respect to how the device needs to be formed should be defined. The most used materials in the production of upper limb prosthetics and orthoses include thermoplastic, thermoplastic elastomer and very light composites, each of which offers strength, flexibility and comfort to some degree.
4. After selecting the design and materials, the 3D printing process can start. Techniques such as Fused Deposition Modeling (FDM) or Selective Laser Sintering (SLS) replace solid components in conventional manufacturing with layer-by-layer construction from a digital model, allowing for high precision and complex forms not achievable through conventional processes.
5. Post Processing and Finishing: Following printing, the device goes through post-processing, which may involve cleaning, smoothing surface finishes, and joining numerous components (if necessary). To improve comfort and functionality, additional features like as padding or straps may be incorporated.
6. Fitting and Adjustment: The printed prosthesis or orthosis is fitted to the patient and adjusted as needed to achieve maximum comfort and function. Iterations are simply controlled with 3D printing.
7. Follow-up and Iteration: Regular follow-up sessions are suggested to monitor the patient's improvement and the device's functionality. Based on these evaluations, more adjustments can be made

to ensure that the device continues to fulfill the patient's demands.

This is how 3D printed orthotics and prosthetics gain what is very arguably the highest level of functionality while, at the same time, offering customized tailoring to individual patients' unique anatomical requirements, adding value over traditional methods regarding comfort, cost, and efficiency.

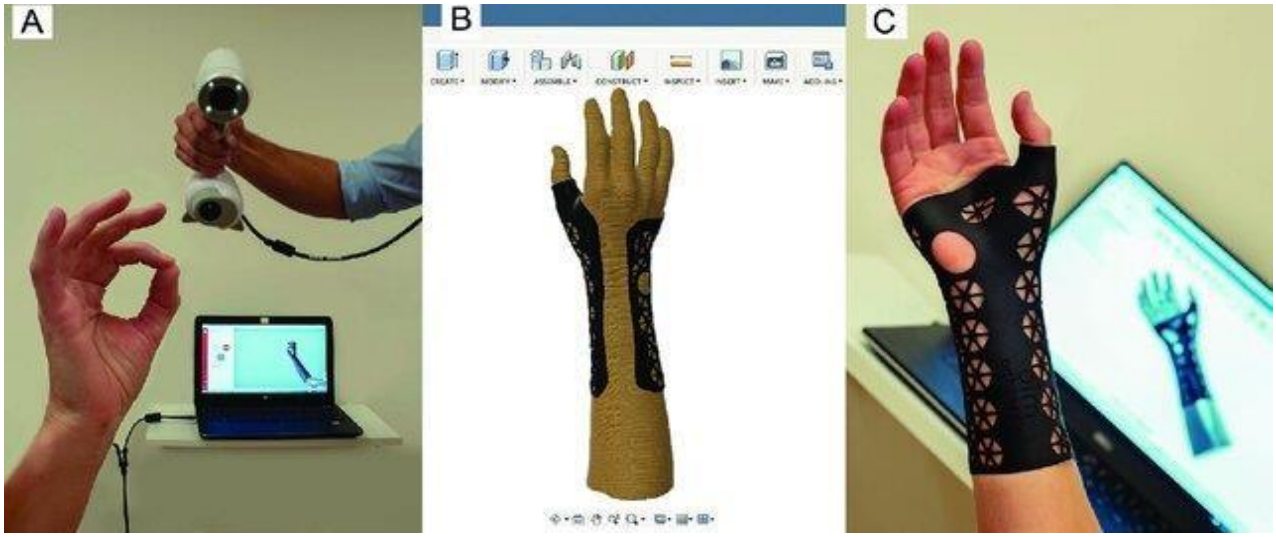

Figure 1. Production process of the 3-dimensional (3D)-printed orthosis. (A) Scanning the hand and forearm, (B) designing the orthosis based on the digital model of the hand, and (C) the 3D-printed orthosis (Oud et al., 2021).

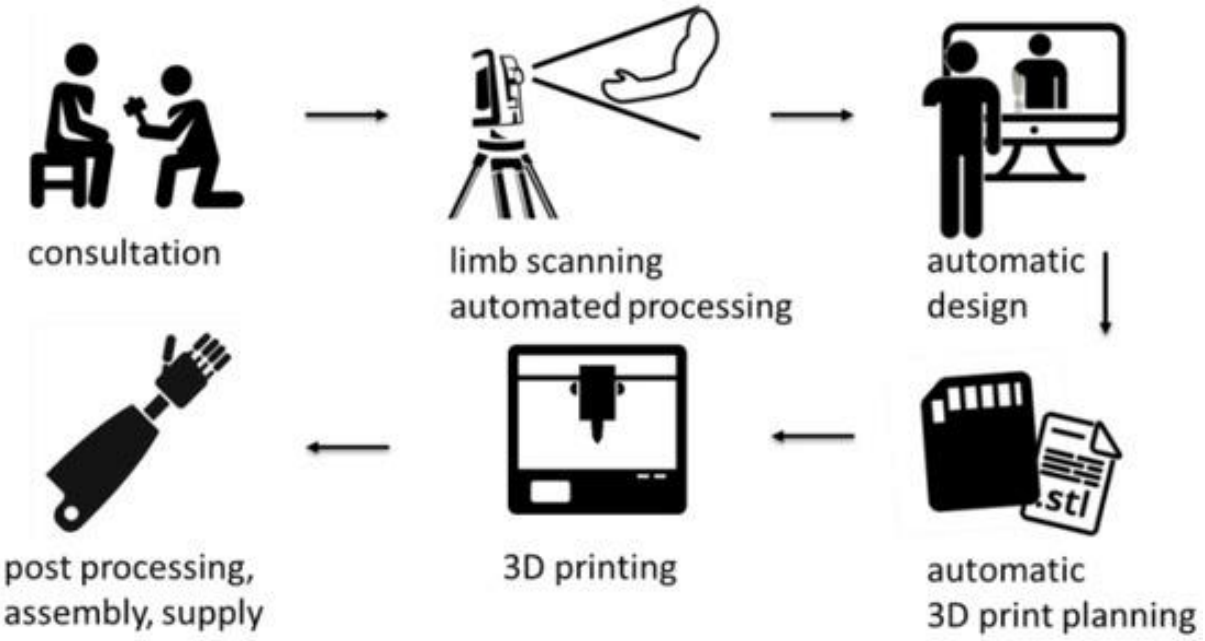

Figure 2. Manufacturing workflow of the 3D-printed upper limb prosthesis. The entire process including: (1) measurement and scanning of the limb stump, (2) customization, (3) printing, and (4) assembling of the components (Górski et al., 2021).

4. Benefits of 3D printing for upper limb orthotics and prosthetics

- Personalization and added comfort: Perhaps the most significant advantage of 3D printing is the ability to produce devices entirely customized for each patient, which significantly increases comfort and improves function. Prostheses and orthoses can be tailored to the anatomical peculiarities of each user, thus maximizing rehabilitation (Pathak et al., 2023).
- Aestheticism and Lightness: Devices produced from 3D printing may be made aesthetically more pleasing and lighter than what performing them by traditional means has to offer. This increases the acceptance of the devices as well as comfort on an everyday basis (Mian et al., 2023).
- Reduced lead times for production: Additive Manufacturing can drastically shorten lead times for devices from several weeks to just days. This is a great step forward in patient care, especially in cases of emergency or where the equipment must change in keeping with evolving pathologies (Chen et al., 2020)
- Cost reduction: In place of saving, significant savings are to be gained from the application of 3D printing. This includes savings in labor, materials, and manufacturing steps; plus, increased responsiveness by on-demand manufacture of prosthetics and orthotics decreases the costs associated with inventory (Cheo et al., 2024).

5.Challenges and limitations of 3D printing in upper limb orthotics and prosthetics:

3D technology for printing saw a welcome development, but there still remains innumerable challenges when it comes to their application with regards to medical devices: Accuracy and fit continue to be the most significant limitations since the functionality and safety of devices can be critically affected by any modeling or manufacturing mistakes (Iftekar et al., 2023). A further limitation is the strength and durability of 3D printed materials, which have improved but fail to achieve the stringent requirements of medical devices, especially prostheses, subjected to daily wear and tear (Ko, 2018)). Material constraints of 3D printing remain because available materials are still much more limited compared to traditional prosthetics and orthotics manufacturing. Therefore, further research and development of biocompatible, flexible, and stronger materials are needed (Behm et al., 2018). Also, though the cost of such technologies was expected to lessen the financial burden, the dual barriers of accessibility and cost were still there, especially in developing countries where the requisite infrastructure for the widespread adoption of this technology is lacking.

6.Future opportunities and prospects:

The present status of research in 3D printing for orthotics and prosthetics is highly promising thanks to future technological advances in bioactive polymers and artificial intelligence for personalizing products even more (Gutierrez et al., 2023). These would provide even better and much more individualized solutions for patients. Accessibility improvements could transform healthcare by reducing the cost of orthotic and prosthetic devices for many patients, especially in low-resource settings (Hassan and Wong, 2023). Besides, mass customization where a large number of products can be produced, individually tailored devices that meet the needs of each

patient may be produced without raising costs or extending the time for production (Shaikh, 2024). This combination of new technological innovations and better accessibility is capable of changing the face of the future of prosthetic and orthotic care all around the world.

7.Conclusion:

Revolutionized upper-limb 3D printing technologies-based manufacturing orthoses and prostheses, which brings personalized approaches to each patient's unique needs in terms of anatomy. This makes it possible to improve the comfort and functional performance of devices; thus, improving patient satisfaction and effectiveness devices. Cost-effective and shorter lead times mean that orthotic and prosthetic devices would become less expensive and made available quickly, promoting even more treating options in countries with lower healthcare capacity. However, works still have to be done concerning the perfecting of the fit of the devices, their lifespan, and easy access within resource-limited countries. There is a lot of room for improvement as far as new materials and technical improvements, along with investing in infrastructure are concerned. Therefore, 3D printing can revolutionize rehabilitation and personalized treatment approaches, making them cost-effective, efficient, and effective for patients.

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Article N°3, Vol 1, No 1

Interoperability of Health Systems: Challenges and Perspectives for Improving Care

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Abstract: This study analyzes the difficulties and consequences of the lack of ***interoperability*** in the Moroccan healthcare system. The aim is to quantify the extent of redundant examinations, assess the impact on medical errors and treatment delays, estimate the financial burden on patients, and gather qualitative information from patients and healthcare professionals. The novelty of this research lies in its mixed-method approach, combining ***quantitative analysis*** of healthcare data with ***qualitative perspectives*** from patients and professionals. We analyzed data from a variety of sources, including the Ministry of Health, local hospitals and public health facilities, and conducted patient surveys and interviews with healthcare professionals. The main findings indicate that 20- 30% of examinations are redundant, 15-20% of medical errors are linked to missing information, and patients wait 2-4 weeks for an appointment with a specialist in urban areas and 2-3 months in rural areas. These difficulties lead to ***increased costs*** and ***health disparities***, with 60% of patients reporting having to repeat their medical history.

Keywords: **I**nteroperability, Quantitative analysis, Qualitative perspectives, Increased coasts, Heath disparities.

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1. Introduction

This study delves into the specific hurdles and repercussions stemming from the lack of interoperability within the Moroccan healthcare system. We will examine the prevalence of redundant tests, the influence on medical errors and treatment delays, and the financial burden imposed on patients. Furthermore, we will investigate the viewpoints of both patients and healthcare professionals concerning the necessity for enhanced interoperability.

2. Methodology

This study will employ a mixed-methods approach, combining quantitative and qualitative data collection and analysis methods.

2.1. Quantitative analysis

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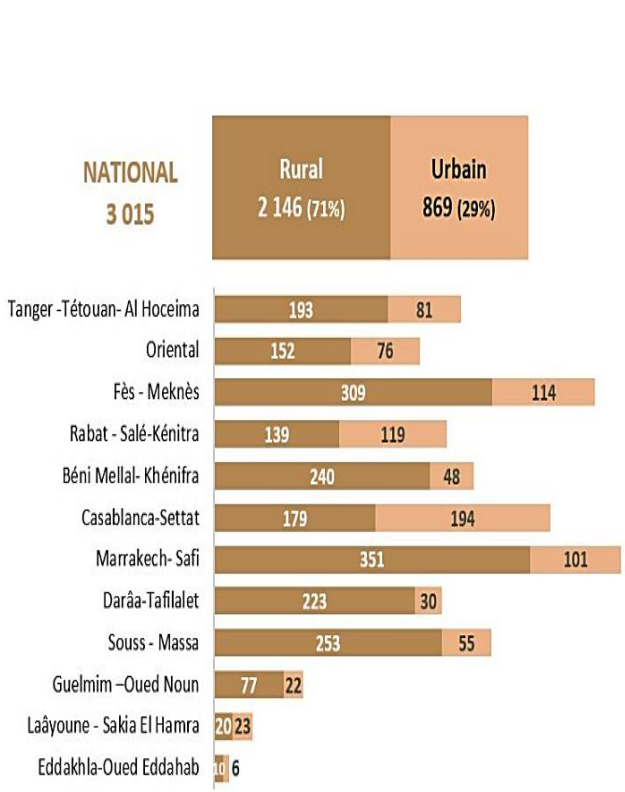

876	433	837	684	185
Centre de santé Rurale Niveau 1	Centre de santé Rurale Niveau 2	Dispensaire Rural	Centre de santé Urbain Niveau 1	Centre de santé Urbain Niveau 2
66	64	63	69	12
70	29	53	61	15
110	56	143	90	24
76	24	39	91	28
80	50	110	43	5
109	23	47	145	49
168	62	121	85	16
67	53	103	21	9
94	54	105	36	19
29	13	35	18	4
7	1	12	21	2
0	4	6	4	2

Table 1: The distribution of Primary Healthcare Establishments by region and setting in Morocco for the year 2022.

The distribution of primary health care establishments in Morocco (HCP). shows a significant investment in primary care, with a total of 3,015 establishments nationwide. The distribution between rural and urban areas is 2,146 (71%) in rural areas and 869 (29%) in urban areas. This distribution suggests that primary health care services are widely accessible, particularly in rural areas where the need for accessible healthcare is often greater. The breakdown of establishments by type and level (level 1 and 2 health centers, dispensaries, and urban centers) provides a comprehensive overview of the primary care infrastructure. This information is valuable for understanding the capacity and distribution of primary care services, which is relevant to our study on interoperability. The extensive network of primary health care facilities, especially in rural areas, highlights the potential impact of improved interoperability in enhancing primary care services and health outcomes.

This data reveals a clear upward trend in the need for healthcare services across both urban and rural areas from 2018 to 2024. While urban populations are consistently larger, both areas show increases across all categories, with children under five and women of reproductive age experiencing the most significant growth. This suggests a pressing need to bolster maternal and child health resources, expand family planning services, and tailor healthcare delivery to meet the unique challenges of both urban and rural environments. Furthermore, the data highlights potential strain on existing healthcare systems and the risk of widening health inequities if access to care is not improved. A deeper dive into the socioeconomic factors and health determinants influencing these trends would provide valuable insights for developing effective interventions and ensuring equitable healthcare access for all (CHI Ibn Rochd).

Années	2018	2019	2020	2021	2022	2023	2024
Population totale							
Urbain	22 072 883	22 494 198	22 992 551	23 430 550	23 868 079	24 304 587	24 739 730
Rural	13 405 510	13 402 189	13 320 688	13 297 356	13 272 865	13 247 340	13 220 899
National	**35 478 393**	**35 896 387**	**36 313 239**	**36 727 906**	**37 140 944**	**37 551 927**	**37 960 629**
Naissances attendues							
Urbain	367 639	371 010	396 268	399 301	401 765	403 727	405 197
Rural	312 224	310 596	286 716	284 820	282 973	281 166	279 506
National	**679 863**	**681 606**	**682 984**	**684 121**	**684 738**	**684 893**	**684 703**
Enfants âgés de moins d'un an							
Urbain	355 691	359 153	387 648	391 355	394 448	396 986	399 030
Rural	298 450	295 584	281 358	279 570	277 847	276 170	274 532
National	**654 141**	**654 737**	**669 006**	**670 925**	**672 295**	**673 156**	**673 562**
Enfants âgés de 12-23 mois							
Urbain	348 169	352 034	382 480	386 832	390 561	393 682	396 252
Rural	291 179	287 764	279 692	277 680	275 946	274 276	272 649
National	**639 348**	**639 798**	**662 172**	**664 512**	**666 507**	**667 958**	**668 901**
Enfants âgés de moins de 5 ans							
Urbain	1 762 026	1 784 411	1 894 643	1 918 799	1 940 244	1 958 908	1 974 752
Rural	1 490 375	1 486 976	1 398 434	1 389 466	1 380 297	1 371 222	1 362 529
National	**3 252 401**	**3 271 387**	**3 293 077**	**3 308 265**	**3 320 541**	**3 330 130**	**3 337 281**
Femmes en âge de reproduction (15 à 49 ans)							
Urbain	6 144 789	6 239 913	6 352 694	6 450 109	6 544 188	6 637 134	6 730 816
Rural	3 273 205	3 209 843	3 166 039	3 119 923	3 072 201	3 024 761	2 979 189
National	**9 417 994**	**9 449 756**	**9 518 733**	**9 570 032**	**9 616 389**	**9 661 895**	**9 710 005**
Femmes mariées en âge de reproduction (15 à 49 ans)							
Urbain	3 406 628	3 459 367	3 547 189	3 601 581	3 654 113	3 706 013	3 758 323
Rural	1 985 792	1 947 040	1 940 018	1 911 759	1 882 516	1 853 451	1 825 523
National	**5 392 420**	**5 406 407**	**5 487 207**	**5 513 340**	**5 536 629**	**5 559 464**	**5 583 846**
Femmes âgées de 30 à 49 ans							
Urbain	3 365 771	3 441 083	3 518 765	3 616 980	3 715 235	3 811 177	3 903 153
Rural	1 615 265	1 583 207	1 581 741	1 562 239	1 538 485	1 510 806	1 479 380
National	**4 981 036**	**5 024 290**	**5 100 506**	**5 [illegible]79 219**	**5 253 720**	**5 321 983**	**5 382 533**
Femmes âgées de 40 à 69 ans							
Urbain	3 524 636	3 652 817	3 550 845	3 669 135	3 786 432	3 903 927	4 022 425
Rural	1 721 569	1 745 160	1 683 298	1 701 905	1 717 292	1 731 028	1 744 132
National	**5 246 205**	**5 397 977**	**5 234 143**	**5 371 040**	**5 503 724**	**5 634 955**	**5 766 557**
Source : SEIS/DPE/DPRF							

Table 2: Evolution of target populations for health programs between 2018 and 2024 by area.

2.2. Qualitative analysis

Qualitative analysis of patient and healthcare professional experiences provides critical insights into the human aspects of healthcare. By exploring patient perspectives on illness, communication, decision-making, and access to care, we can better understand their needs and priorities. Similarly, examining healthcare professional perspectives on their roles, challenges, and ethical dilemmas can help improve healthcare delivery and support. Utilizing methods like interviews, focus groups, and observations, researchers can gather rich data to analyze and understand the complex interplay of factors shaping healthcare experiences. This knowledge

can then be used to enhance patient- centered care, improve communication, and address systemic issues within healthcare systems [3].

3. Results

Qualitative research consistently reveals that patients highly value healthcare providers who demonstrate empathy and clear communication, making them feel understood and respected. They also express a strong desire for shared decision-making, wanting to actively participate in their care and make informed choices that align with their personal values. However, access to timely and affordable care remains a significant obstacle for many, particularly in rural areas where resources may be limited.

From the healthcare provider perspective, qualitative findings highlight the growing burden of increasing workloads and administrative tasks, contributing to burnout and compassion fatigue.

Furthermore, healthcare professionals grapple with complex ethical dilemmas daily, requiring ongoing support and guidance. These insights emphasize the need for improved communication training, patient-centered care models, increased access to services, and robust support systems for healthcare professionals to foster a more compassionate and sustainable healthcare system.

4. Discussion

The findings we discussed earlier, highlighting the growing need for healthcare services, the urban- rural disparities, and the importance of patient-centered care and healthcare professional support, underscore the need for a comprehensive approach to healthcare in Morocco. These results, coupled with the challenges of managing and interpreting large datasets, strongly suggest the need for a robust and interoperable software solution. Such a software could facilitate better data management, enhance communication and collaboration among healthcare stakeholders, and support evidence-based decision-making for improved healthcare delivery. Therefore, it is crucial to conceptualize and develop interoperable software in Morocco to address these pressing needs and ultimately enhance the quality of healthcare for all citizens.

5. Conclusion

In conclusion, the escalating demand for healthcare services in Morocco, coupled with the complexities of managing extensive data and ensuring equitable access to care, necessitates innovative solutions. Developing an interoperable software has the potential to revolutionize

healthcare in Morocco. By streamlining data management and analysis, this software can empower informed decision-making and facilitate targeted interventions. Furthermore, it can enhance communication and collaboration among healthcare stakeholders, fostering a more coordinated and efficient system. By promoting patient-centered care and providing support for healthcare professionals, this innovative tool can address pressing challenges and pave the way for a more responsive, equitable, and sustainable healthcare system in Morocco.

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Article N°4, Vol 1, No 1

Behavioral approach of a morwak ultrafiltration device

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Abstract: The increase in chronic kidney diseases and associated renal function disorders has led to a growing demand for portable and effective filtration devices. In this context, the MorWAK portable ultrafiltration system emerges as an innovative solution aimed at transforming the management of renal failure. This device stands out for its structural approach, which optimizes the filtration of metabolic waste while offering flexibility of use for patients in rural areas or during travel. The architecture of the MorWAK is based on a modular design, allowing for rapid adaptation to variations in environmental and clinical conditions. By integrating advanced ultrafiltration membranes and smart sensors, this device ensures effective separation of toxins and fluids while minimizing the risks of infection and complications (Jha et al., 2016). This research aims to analyze in depth the operating principles of the MorWAK, focusing on the interactions between biological fluids and membranes. Preliminary studies have shown that the structure of the membranes, as well as their porosity and surface characteristics, play a crucial role in the effectiveness of the filtration process. By optimizing these parameters, it becomes possible to enhance the performance and reliability of the device (Salani et al., 2018).
Furthermore, the study will also address the impact of MorWAK technology on patients' quality of life. The accessibility of a portable filtration treatment can reduce the burdens of dialysis sessions in hospital settings, thus providing greater freedom for users. The ultimate goal of this research is to provide recommendations for the future development of innovative renal filtration devices that combine efficiency, comfort, and sustainability, thereby contributing to the improvement of care for individuals suffering from kidney diseases.

Keywords: MorWAK; ultrafiltration, innovative, flexibility; modular; freedom.

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1. Introduction

This study mainly focuses on the structural approach of an innovative portable ultrafiltration device for the kidneys. Its primary objective is to provide a detailed analysis of the design, operation, and performance of this groundbreaking device, while highlighting its numerous potential clinical applications.

Today, ultrafiltration plays a crucial role in the treatment of kidney diseases. This in-depth study presents a practical and portable solution that fully addresses this important medical need. This marks a promising advancement in the field of renal health, offering new hope to patients and significantly improving their quality of life (Touam et al., 2019).

With its portability and innovative nature, this device can be effectively used in various clinical environments, whether in hospitals, specialized clinics, or even at home. The careful design of this device not only ensures maximum efficiency in filtering unwanted substances but also facilitates ease of use and reduced maintenance.

Additionally, it is essential to emphasize that this device has been rigorously tested and validated, thus ensuring its reliability and safety for long-term use. In conclusion, this pioneering study paves the way for new perspectives and opportunities in renal ultrafiltration technology, providing a practical, portable, and effective solution to significantly enhance the quality of life for patients with kidney diseases (Olson et al., 2009).

The impact of this innovation is undeniable, as it allows patients to receive high-quality renal treatment wherever they are, without compromising their mobility or independence. This revolutionary technology offers a valuable alternative to traditional dialysis methods, enabling patients to enjoy a better quality of life with fewer constraints and limitations.

The advantages of this device are numerous and significant. It allows precise and effective filtration of toxins and metabolic waste, thereby eliminating the risks of undesirable substance accumulation in the body. Moreover, its ease of use ensures that patients can independently manage their treatment without the need for regular visits to hospitals or clinics for dialysis. This increased mobility and independence are crucial for improving the quality of life for renal patients, allowing them to lead more active and fulfilling lives.

Not only does this device offer practical benefits, but it also presents considerable economic advantages. By reducing patients' dependence on traditional dialysis methods, it enables more

efficient use of medical resources, thereby lowering the costs associated with renal care. This opens the door to new possibilities for renal care for patients around the world (Bejjanki et al., 2020).

The portability and user-friendliness of this device make it an attractive choice for the medical community, as it provides a practical and cost-effective solution to improve the quality of life for patients with kidney diseases. Ongoing research and development of this innovative technology are essential to provide cutting-edge renal treatments and to meet the changing needs of patients.

Through this study and this revolutionary device, a new era of renal care is emerging, creating hope and offering better quality of life for those who need it most. Collaboration among healthcare professionals, researchers, and engineers has made this exciting advancement possible, and it is important to continue supporting and promoting innovations in the field of kidney diseases.

The structural modeling of a new portable ultrafiltration device, Morwak, is essential for several fundamental reasons aimed at optimizing its efficiency and safety. In a context where chronic kidney diseases affect an increasing number of patients, the need to develop accessible and practical treatment solutions is paramount. This modeling will allow for the analysis and simulation of the device's behavior, thereby facilitating the optimization of its design to ensure the treatment of hypervolemia primarily encountered in cases of End-Stage Kidney Disease (ESKD) and Congestive Heart Failure (CHF; Hmida, (s.d.)). It plays a key role in validating the system's performance, ensuring that the device can operate effectively under varied conditions while adhering to portability constraints. Furthermore, this approach will enable the anticipation and minimization of risks of clinical complications while integrating intelligent control systems to monitor and regulate the functioning of the device. Finally, structural modeling contributes to creating an ergonomic and durable device that meets the growing demand for mobile and accessible treatment options for patients (Hmida, (s.d.)).

In conclusion, this innovative portable ultrafiltration device represents a major achievement in renal health, offering a practical and effective solution to enhance patients' quality of life. Its innovative nature, reliability, and safety have been rigorously demonstrated, paving the way for broader use of this promising technology. As we move towards an improved future of renal care, it is essential to continue supporting the research and development of innovative devices to provide superior quality treatments for patients with kidney diseases (Abbott, 2024).

The MorWAK Portable Ultrafiltration Device has been designed to address the growing incidence of kidney diseases and their associated complications. This innovation represents a significant

milestone in renal healthcare, offering an efficient, portable, and user-friendly solution for ultrafiltration. By integrating advanced technologies with practical functionality, MORWAK facilitates real-time monitoring and promises to revolutionize kidney care, improving patients' quality of life.

The Importance of Ultrafiltration in Renal Health

Ultrafiltration plays a pivotal role in managing kidney diseases by filtering metabolic waste and excess fluids from the body. While traditional dialysis methods are effective, they impose significant constraints, including frequent hospital visits and limited mobility for patients. The MorWAK device addresses these limitations by providing a portable alternative that allows patients to receive effective treatments at home, during travel, or in rural areas where access to specialized care is limited (Abbott, 2024).

Efficient and Adaptable Design

MorWAK's structural design prioritizes modularity and adaptability, enabling it to operate efficiently in diverse clinical and environmental conditions. Its advanced ultrafiltration membranes and integrated smart sensors ensure precise toxin and fluid filtration while minimizing infection risks. With an ergonomic design, the device is easy to use and requires minimal maintenance, empowering patients to manage their treatment independently.

Preliminary research has emphasized the importance of membrane structure, porosity, and surface characteristics in enhancing filtration performance. Structural modeling has been utilized to optimize these parameters, ensuring consistent and reliable operation while meeting the diverse needs of patients (Zahidi et al., 2024).

Clinical Applications and Improved Patient Outcomes

MORWAK offers broad clinical applications, ranging from hospital and clinic-based care to home treatments. Its portability and innovative features grant patients greater independence, reducing reliance on traditional dialysis centers. This mobility is especially valuable for those living in remote or underserved regions, allowing them to maintain an active lifestyle while managing their condition effectively (Jha et al., 2016).

The impact of MorWAK on patient quality of life is profound. By alleviating the logistical and physical burdens of conventional dialysis, the device enhances mental and physical well-being.

Patients gain the freedom to participate in daily activities with fewer interruptions, fostering a sense of empowerment.

Economic Benefits and Systemic Improvements

In addition to clinical advantages, MorWAK offers significant economic benefits. By decreasing dependence on traditional dialysis infrastructure, the device optimizes healthcare resources and reduces overall treatment costs. Its affordability makes it an appealing option for both patients and healthcare providers, facilitating widespread adoption in various settings.

The modular design of MorWAK simplifies manufacturing and maintenance, contributing to its cost-effectiveness. Continuous research and development efforts aim to further improve its efficiency and expand its applicability, ensuring the device remains a leader in renal care innovation (Costanzo et al., 2017).

Structural Modeling and Safety

Structural modeling is a critical component of MorWAK's development, enabling detailed simulations and analyses to optimize its design. This ensures the device's safety and efficacy under various conditions. By addressing key challenges such as hypervolemia and end-stage kidney disease (ESKD), modeling allows researchers to anticipate potential complications and integrate intelligent control systems for real-time monitoring.

This proactive approach not only enhances device performance but also reduces clinical risks, making it a dependable solution for long-term use. Smart sensors and advanced monitoring technologies further ensure personalized treatments tailored to individual patient needs (Zahidi et al., 2024).

Future Potential of MorWAK

MORWAK signifies a promising advancement in renal care, paving the way for further innovations in ultrafiltration technology. Its success highlights the importance of collaboration among healthcare professionals, engineers, and researchers to address complex medical challenges. As the demand for accessible and practical treatments increases, portable and efficient devices like MORWAK will play a pivotal role in meeting these needs (Roques, 2013).

2. General structural approach

The structure of MorWAK is distinguished by the use of biocompatible and lightweight materials, ensuring comfort and safety during prolonged use. Moreover, the innovative arrangement of the components minimizes the footprint while optimizing performance. Each element, from the filtration module to the integrated monitoring sensors, has been designed to ensure maximum reliability and simplified maintenance(Jha et al., 2016).

By exploring this structural approach, we highlight the engineering and design principles that make MorWAK a significant advancement in the field of portable medical devices. This innovation embodies a concrete response to the limitations of conventional solutions, integrating practicality, effectiveness, and adaptability to the specific needs of patients (Salani et al., 2018).

2.1. Detailed structural approach to morwak

The objective is to obtain a systemic and integrated representation that facilitates a deep understanding of the system, allows the identification of vulnerability points and improvement opportunities, and supports informed decision-making regarding its future evolution(Zahidi et al., 2024).

The structural modeling of MorWAK is an iterative process that involves close collaboration between domain experts and modeling specialists. It also requires in-depth data collection and analysis to ensure the validity and reliability of the developed representations(Roques, 2013).

2.2. Structural modelling diagrams

2.2.1. General block diagram

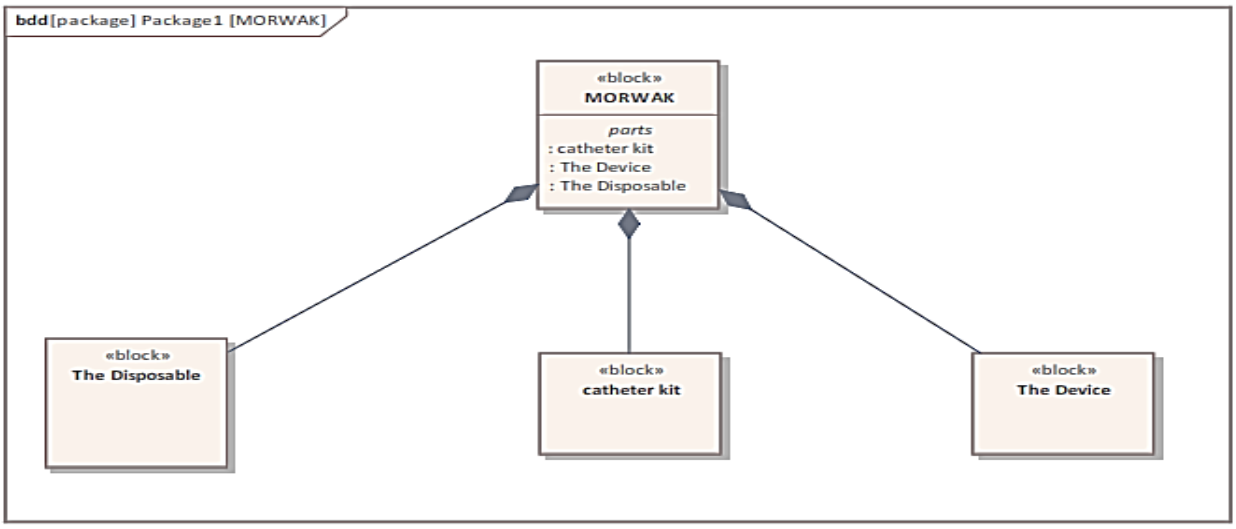

Figure 1. Diagram Sysml 1.

2.2.2. *Detailed block diagram*

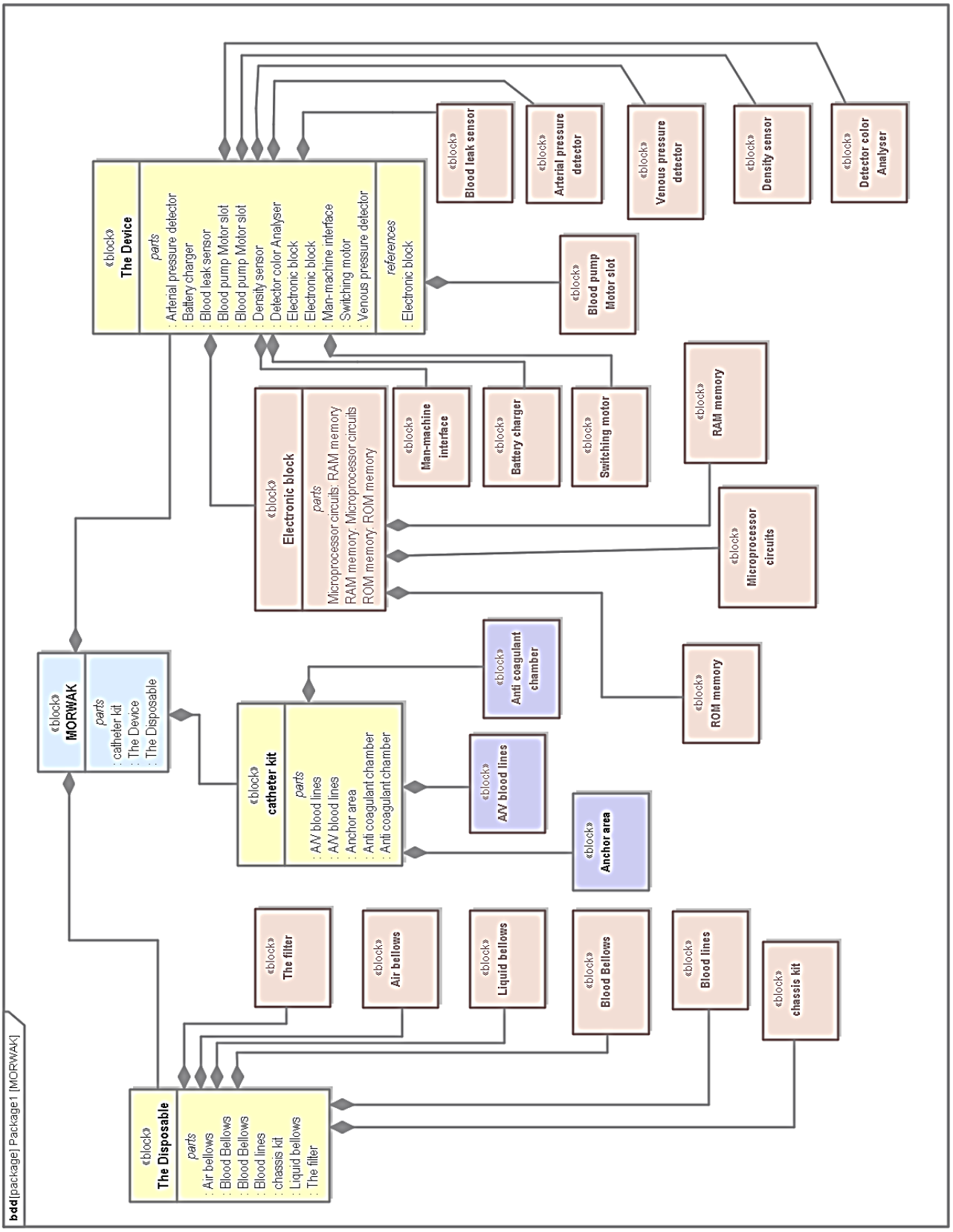

Figure 1. Diagram Sysml 2.

3. Conclusion

While the modeling has addressed many technical challenges, the development and commercialization of MORWAK will require extensive clinical trials, adjustments based on user feedback, and strict adherence to certification and regulatory standards (Roques, 2013).

The MorWAK portable ultrafiltration device showcases the transformative potential of innovative healthcare technologies. By combining efficiency, reliability, and a patient-centric design, it provides an effective solution for managing kidney diseases while enhancing the overall quality of life for patients. Addressing the limitations of traditional dialysis, MorWAK empowers individuals to lead independent and fulfilling lives. Ongoing research and development will continue to drive progress in renal care, offering hope and better outcomes for patients worldwide.

In conclusion, the structural modeling of MorWAK represents a promising breakthrough in portable medical devices, paving the way for more personalized and practical healthcare solutions (Petitclerc, 2001).

4. Acknowledgements

We extend our sincere gratitude to our guiding professors whose invaluable guidance and expertise have been instrumental throughout our research project. Their enlightened advice, dedication, and unwavering support have significantly contributed to the success of this study.

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Article N°5, Vol 1, No 1

Patient radiation protection and quality assurance of therapeutic treatment in radiotherapy

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Abstract: Radiotherapy is an essential modality in the treatment of cancer, combining advanced technology with rigorous medical protocols to ensure optimal therapeutic results. However, it also involves risks inherent to exposure to ionizing radiation, both for the patient and for medical personnel. This article examines the mechanisms and strategies of patient radiation protection and their integration into treatment quality assurance systems. By emphasizing dose management, equipment control and continuous evaluation of procedures, the goal is to minimize risks while ensuring therapeutic effectiveness. A collaborative approach involving medical physicists, oncologists and radiotherapists is also discussed to strengthen the quality of care.

Keywords: Radiation protection in radiotherapy, Quality control, Dosimetry, VMAT, RC3D, TPS.

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1. Introduction

Radiotherapy occupies a central place in the treatment of many oncological pathologies, offering an alternative or complement to surgery and chemotherapy. Advances in techniques, such as conformal radiotherapy and image-guided radiotherapy, have improved the precision of treatments, thereby reducing side effects while increasing clinical effectiveness. However, with this increased sophistication comes complex safety and quality challenges.

Radiation protection of the patient constitutes a priority in this context, ensuring that the doses administered are strictly necessary to achieve the therapeutic objectives, while minimizing the exposure of healthy tissues. At the same time, quality assurance, through standardized protocols and continuous assessments, ensures that treatments are carried out with optimal precision and in accordance with best practices.

2. Materials and methods

2.1. Treatment planning system TPS

2.2. TPS-ECLIPSE

Eclipse is an integrated planning ecosystem that combines advanced imaging with precision-driven treatment delivery, enabling clinicians to make the most of radiotherapy's ability to help eradicate tumors.

2.3. Processing techniques

2.3.1. 3D conformal radiotherapy technique (RC3D)

The aim of conformal radiotherapy or 3-dimensional conformal radiotherapy is to seek the best adaptation of the shape of a high value isodose envelope to the exact shape of the target volume. This technique has developed thanks to the arrival of modern imaging means and multileaf collimator (MLC) technology.

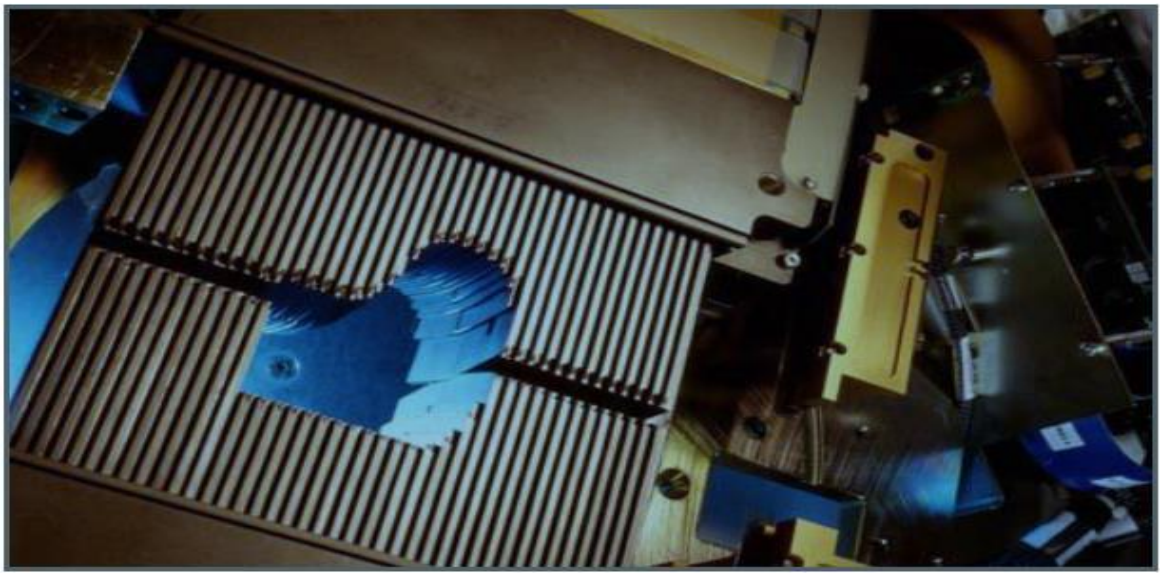

Figure 1: Multileaf collimator

2.3.2. Volumetric Intensity Modulated Arc Therapy (VMAT) technique

VMAT: intensity modulation is obtained by the continuous movement of the blades during irradiation as well as the arm.

This irradiation technique allows the treatment of complex target volumes sometimes enveloping organs at risk. It better protects healthy tissues by only exposing them to minimal doses of irradiation. It also makes it possible to vary the distribution of the dose within the tumor itself.

2.4. Dosimetric quality control of the Varian linear accelerator

In radiotherapy, it is essential to have precise knowledge of the dose delivered by the line accelerator. To be used clinically

Dosimetric control is done to check whether the dose delivered by the machine is constant. This control is based on the dose rate measurement delivered by the linear accelerator for the different energies of photons and electrons at a reference depth and a maximum depth following the IAEA protocol TRS398. It is divided into two steps:

Step 1: Calibration in water (reference dosimetry). The aim of this step is to check the parameters of the dose profile which are homogeneity, symmetry, penumbra and field size. And even PDD measurement to check beam quality.

Step2: Calculation of the dose rate using a worksheet prepared by the IAEA. To carry out absolute dosimetry we use the Farmer Chamber Type 30013. We measure the charges stuck in the chamber (Farmer) using OMNI PRO software.

2.4.1. Tools used:

When carrying out our study, measurement tools were used. These tools are:

- The ionization chamber (Farmer Chamber Type 30013)
- The water tank.
- The electrometer.
- The OMNI PRO data acquisition software

A. The ionization chamber:

The ionization chamber makes it possible to measure a charge (ionization). This charge can then be converted to an absolute dose. The ionization chamber consists of an air cavity between two electrodes.

Figure 2: Farmer Chamber Type 30013 ionization chamber

B. The water tank:

The water tank represents one of the important measuring elements in radiotherapy. The measurements that can be carried out are: depth yield, dose profile, absolute dose, etc.

The water tank is made up of three motors and three potentiometers (individual movement) allowing the movement of the ionization chamber in the three planes of space.

The water tank forms a cube with a total capacity of 0.148 m³ (length: 59.4 cm, width: 49.6 cm, depth: 50.25 cm). Installation must be as careful as possible so as not to distort the measurements.

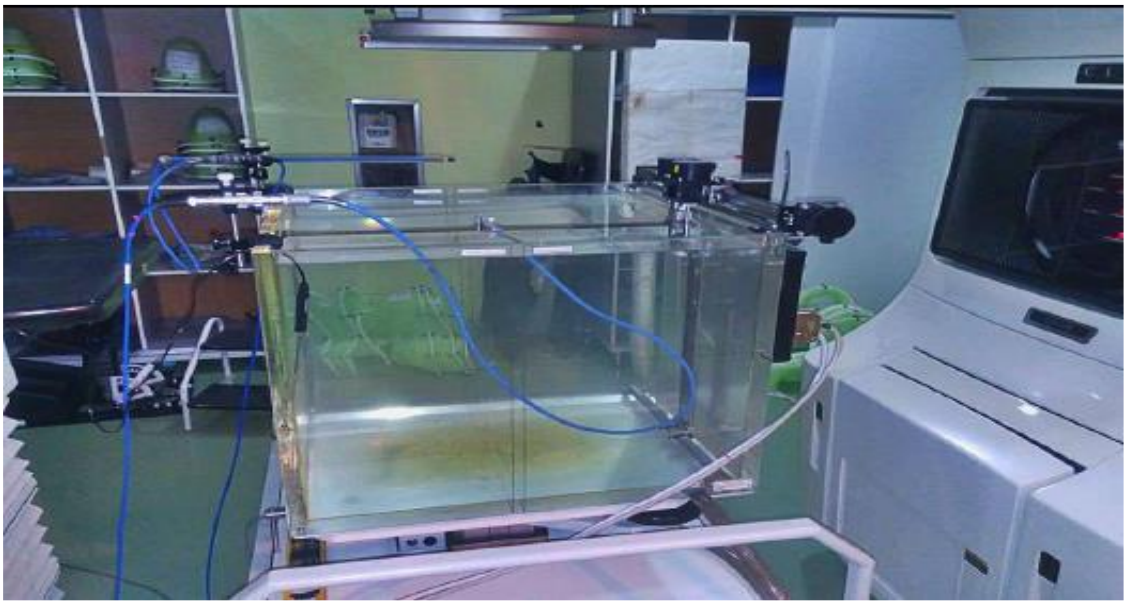

Figure 3: water tank

C. MNI PRO data acquisition software:

This software allows data to be collected after irradiation: depth yield, dose profile and absolute dose.

The movement of the ionization chamber via the movement motors is carried out using this software. After having defined the field size, the energy, the source/water surface distance (SSD, Skin Source distance), we can carry out our measurements.

D. The electrometer:

Electrometers are used to measure a charge (nano Coulomb) on the electrodes of the ionization chamber. This charge is then converted into absorbed dose (Gray).

Figure 4: UNIDOS PTW electrometer

E.Thermometer and barometer:

The accuracy of the barometers and the thermometer are used to determine the air density correction factors for absolute dosimetry.

Figure 5: OPUS 20 thermometer and barometer

2.4.2. Calibration in water (reference dosimetry):

A. Experimental setup of the water tank:

Installing the water tank is a very important step for data collection. Its installation must be as accurate as possible in order to optimize the precision of the measurements taken. First of all, it is necessary to make the center of the tank coincide with that of the directing beam of the linear

accelerator. Simply use the reticle located in the head of the accelerator and superimpose it on the cross at the bottom of the tank. To facilitate installation, it is possible to use repositioning lasers. The tank is then filled with distilled water. The water source/surface distance (SSD) must be set to 100 cm using the telemeter in order to position the ionization chamber at the isocenter of the water tank.

Figure 6: Water tank being assembled

❖ **Positioning of the measuring chamber:**

For this step we use the Farmer Chamber Type 30013 ionization chamber as a reference and even for the measurement (of PDD and profile). The reference chamber which is used to check the linearity of the MUs is placed on a support above the tank. It must be placed at the edge of the light field. The two chambers are then connected to the TANDEM electrometer, which is itself connected to the OMNI PRO software.

➢ **Photons:**

✓ **Profile measurement:**

We can define from the dose profile curve: penumbra, field size, homogeneity and symmetry.

A. Symmetry: Typical specifications for symmetry are that any two points, any dose on a beam profile distant from the patient's central axis, must be less than 2% of each other. The symmetry is then calculated from:

$$S = 100\% \times ((area\ left + area\ right)/(area\ left - area\ right))$$

B. flatness: the flatness of the beam F is evaluated by determining the values of the maximum dose points Dmax and minimum Dmin on the beam profile in the 80% of the central part of the beam width, and this is the ratio of:

$$\boldsymbol{F}=\mathbf{100}\%\times((\boldsymbol{Dmax}-\boldsymbol{Dmin})/(\boldsymbol{Dmax}+\boldsymbol{Dmin}))$$

C. Field size: For a field size of 10x10 cm2 and a depth of 10cm in water, scans are carried out in the direction of X and Y. From the OMNI PRO system we deduce the size of the irradiation field.

D. Penumbra of the irradiation fields: The penumbra is measured for each energy from the dose profiles produced for the study of homogeneity and symmetry. It is characterized by the lateral distance between 80% and 20% of the dose on the axis of the beam, called physical penumbra measured on the main axes of the square fields.

- **Procedure :**

We set the Farmer Chamber Type 30013 measuring chamber to x=y=0 and to the depth Zref.

We scan the room along the x and y axis and start calculating our profile with the OMNI PRO software which automatically calculates homogeneity and symmetry. The study will cover a field of size 40cm x 40cm:

- **Result and discussion:**

The chamber being placed at $Zréf=5cm$, it moves along the two axes x and y, this allows us to obtain the following results:

Table: Control of homogeneity, symmetry, Penumbra and field size for photons

	Homogénéité		Symétrie		pénombre (mm)	la taille de champ (mm)
Energie	**Mensuel**	**Crossplane**	**Mensuel**	**Crossplane**		
6MEV	**2,4%**	**3,1%**	**0,4%**	**2,1%**	**1,00**	**1,99**
18 MEV	**2,3%**	**2,5%**	**0,8%**	**1,9%**	**1,5**	**2,00**
Tolérance	**3%**		**2 %**		**2mm**	**2mm**
Action immédiate	**>3%**		**>2%**		**> 2mm**	**> 2mm**
Fréquence	**Mensuel**					

Inplane: direction of the chamber in the X axis

Crossplane: direction of the room in the Y axis

We also obtain the following dose profile curve:

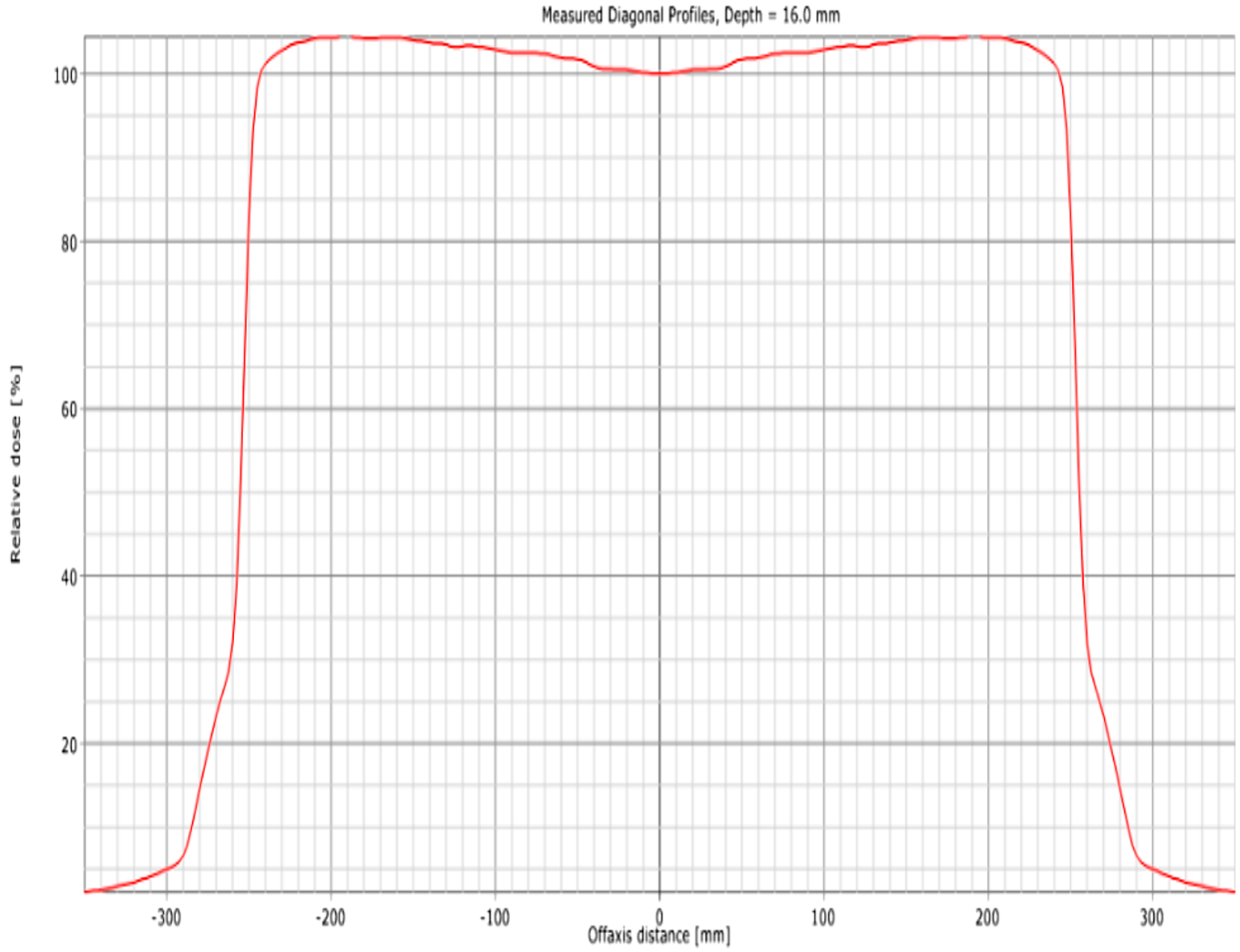

Figure 7: 40X40 field size dose profile for 6MV energy

From the table and the curve we can clearly see that the tolerance of the different examinations was well respected.

- ✓ **PDD measurement: PDD depth performance**

The depth yield curves for photons were measured for a field size (20*20) $cm2$. They are measured from the surface to a depth of 40 cm for the two photon beams and giving the variation of the absorbed dose as a function of the depth in the water on the axis of the irradiation beam at a source-surface distance of the fixed phantom.

- ➢ **Procedure:**

The Farmer Chamber Type 30013 ionization chamber is swept from 0 to 40 cm in depth. From PDD we output a very important parameter, which characterizes the quality of the beam used, which is the tissue-skin ratio TPR20, 10:

Q= TPR = (1,2661x PDD20, 10) – 0, 0595

With:

PDD = $D20/D10$

The parameter TPR20, 10 is defined as the ratio of doses on the central beam axis at the depth of 20cm and 10cm in water obtained with a constant detector source distance of 100cm and a field size of 20X20 $cm2$. The value of TPR20.10 must be between 0.5 and 0.8.

- ➢ **Result and discussion**

By following the previous procedure we obtain the following curves:

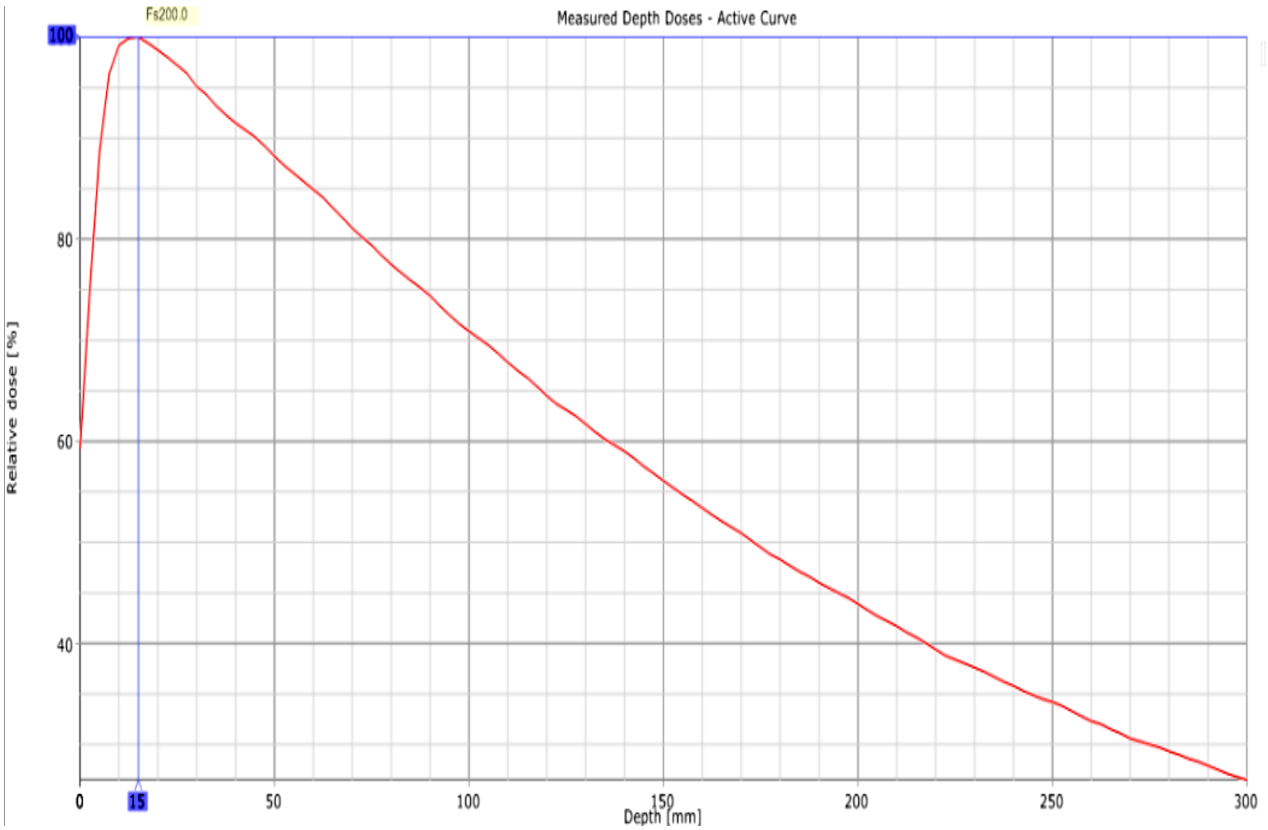

Figure 8: Depth efficiency for the X-ray beam for 6MV energy

As well as the values of TPR20, 10(6MV) and TPR20, 10(18MV) which respect the accepted tolerance:

TPR20, 10(6MV) = 0.681

TPR20, 10(18MV) = 0.772

2.4.3. Routine dosimetry (The Top)

The TOP measurement protocol is identical to that used when measuring the dose under reference conditions: field 10x10 DSP = 100. It makes it possible to control the stability of the dose delivered by the accelerator, that is to say that for a number of monitor units, the accelerator always delivers the same dose (to within 2%) for all the energies of the photons and electrons. This measurement is carried out daily by the DailyQA, each morning we install the DailyQA and we select a 10x10 $cm2$ field then we check its light projection on the control device which must be exact with the field drawn on the device. Once the field control is validated a green button lights up, otherwise, the button will be red and we will use the woorksheet to recalculate the dose rate so that 100UM is worth a rate of 1cGy /UM.

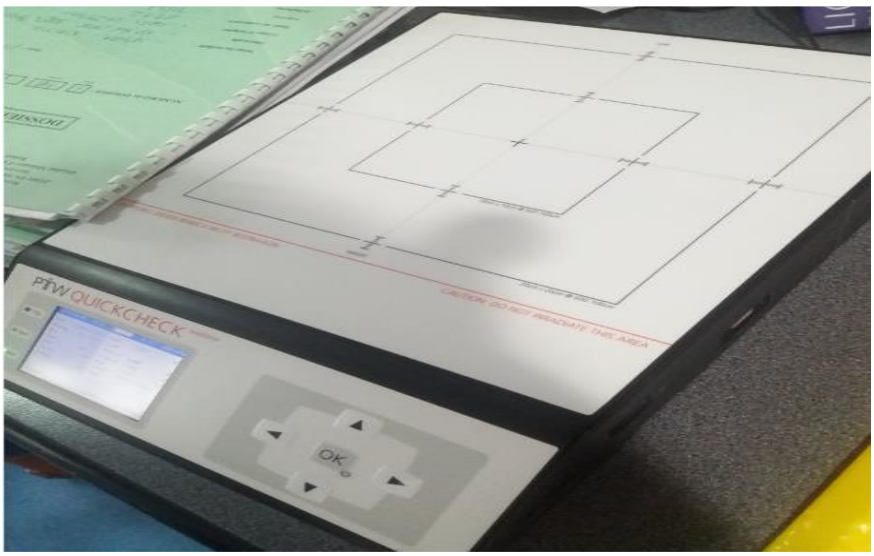

Figure 9: DialyQA device

3. Conclusion:

According to the results obtained for the quality control of the scanner (image quality), and the mechanical and dosimetric control of the accelerator, we can see that all these tests respect the tolerated standards. No problems to report.

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Author Guidelines

Moroccan Journal of Health and Innovation (MJHI)

1. Journal Overview

The **Moroccan Journal of Health and Innovation (MJHI)** is a peer-reviewed scientific journal that publishes original research, literature reviews, and case studies in the fields of health and medical innovation.

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- **Original Research Articles:** Experimental or clinical studies providing new knowledge.
- **Review Articles:** Summaries of recent advances on a specific topic.
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- Full article title
- Names and affiliations of authors
- Corresponding author (name, email address)

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- An abstract of **up to 250 words** (in both English and French)
- **3 to 6 keywords**

4.3 Main Text

Research Articles

1. **Introduction:** Context and objectives
2. **Methodology or Material and Methods:** Description of the methods used
3. **Results:** Presentation of findings
4. **Discussion:** Interpretation and comparison with existing literature

5. **Conclusion:** Summary of main conclusions and future perspectives

Review Articles and Other Types

- Adapt the structure according to the content

4.4 References

Format : APA : Auteur, A. A., & Auteur, B. B. (Année). Titre de l'article. *Nom du Journal, volume*(numéro), pages.
Exemple : Smith, J., & Doe, J. (2023). Impact of AI in healthcare. *Medical Innovation, 12*(3), 45–60.

To cite references within the text of the article, the author(s) should be placed in parentheses along with the year of publication. For example: (Alain et al., 2025); (Alain and Robert, 2025); (Alain, 2025).

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- Disclosure of potential conflicts of interest

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