Team Results Document

GLAsense

University of Glasgow

Team members:

Aayushi Mahesh Kasture
Amelia John
Baitki Shilla
Cong Liu
Jana Alimam Alhusseini
Jiaqi Fan
Jonathan Beck
Morris Mcdiarmid
Shriraghav Sivakumar
Siddhesh Pranav Jadhav
Vivienne Awumee

Supervisor:

Julien Reboud

Coaches:

Chunxiao Hu

August 8th, 2025

SensUs

1. Abstract

We developed a prism-based optical Surface Plasmon Resonance (SPR) system, bringing high sensitivity, combined with Molecularly Imprinted Polymers (MIPs) for specific detection of creatinine and hydrogels for convenient sampling and continuous processing of interstitial fluid, through microneedles. The prototype demonstrated that SPR angle shifts measurements can be supported by a calibration algorithm using optical reference lines and temperature compensation for reliable, accurate sensing. Voltage-driven, electrophoretic washing was designed and tested to enable repeated measurements. This unique biosensor system can be integrated into a novel wearable biosensor embedded in a breathable compression sleeve with Velcro fastening for stable, discreet, all-day use. The device supports continuous sensing, wireless data transfer to a smartphone app, and efficient power management.

Most importantly, although technically promising, a thorough and rigorous co-design study with nine acute kidney injury patients, as well as clinicians and wider stakeholders, led to our development of the Kidney Health Hub, which is a discreet, passive system separating sample collection and sensing. We present a clear pathway for technical and clinical validation, initially focussed on post-kidney transplant patients, to validate diagnostic accuracy with standard blood test data, assess usability by end-users, and evaluate its ability to enable earlier detection of kidney function decline and faster intervention (leading to improved patient care and lower healthcare and societal costs), alongside defined regulatory steps towards potential commercialisation.

In summary, we have demonstrated a key innovation in a miniaturised, calibration-stabilised SPR-MIP biosensor platform with active washing, which can be further integrated into a discreet wearable or home-use format, informed and refined through direct patient co-design.

2. AP award: Biosensor developed for the Eindhoven Testing Event

2.1. Molecular Recognition

After evaluating different biosensing strategies for creatinine detection, we selected a combination of Surface Plasmon Resonance (SPR) and Molecularly Imprinted Polymers (MIPs) to achieve high sensitivity and specificity (Butt, 2025). Hydrogels were incorporated as the transport medium, with potential integration of hydrogel-based microneedles for interstitial fluid (ISF) extraction. In this system, MIPs are immobilised on a gold surface to provide selective recognition of creatinine. These synthetic polymers are produced by polymerising functional monomers and cross-linkers around a creatinine template. Removing the template leaves cavities that are structurally and chemically complementary to the target molecule, enabling specific binding (Arif Topçu et al., 2019; Saylan et al., 2019). We fabricated a PVA PEG PAAm hydrogel layer (Figure 1) that allows passive diffusion of small molecules such as creatinine while maintaining hydration, preserving biomolecular stability, and controlling analyte delivery to the MIP surface (Peppas & Khare, 1993; Thang et al., 2023).

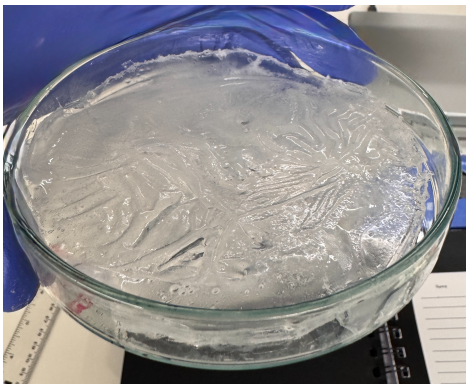

Figure 1: PVA-PEG-PAAm hydrogel diffusion medium for the transport of ISF to the sensing medium.

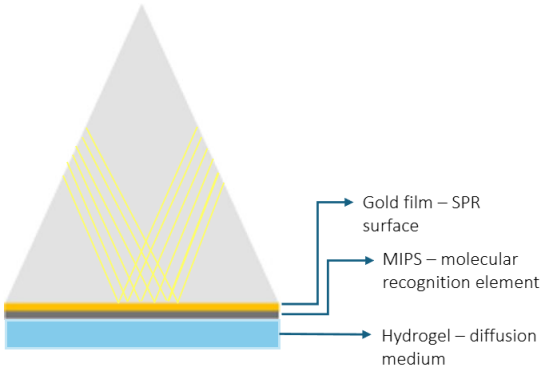

Figure 2: Schematic of the biosensor layers, depicting the hydrogel diffusion layer, MIP recognition layer, and gold-coated surface for SPR detection of creatinine in ISF.

2.2. Physical Transduction

The biosensor uses Surface Plasmon Resonance (SPR) to detect changes in creatinine concentration. Binding of analytes to the gold surface (Figure 2) alters the refractive index, which shifts the resonance angle and produces a measurable displacement of the SPR dark line. To implement this, we built an optical setup consisting of a 625 nm red LED, aspherical condenser lens, polarising beamsplitter, concave mirror, gold-coated right-angled prism, achromatic doublet lens, and a CMOS sensor (Figure 3). Collimated light from the LED is polarised and directed onto the concave mirror, introducing angular divergence before entering the prism to excite surface plasmons at the gold interface. The reflected light is

then focused and imaged by the CMOS sensor for analysis. This setup was later integrated into the final reader instrument (Figure 4).

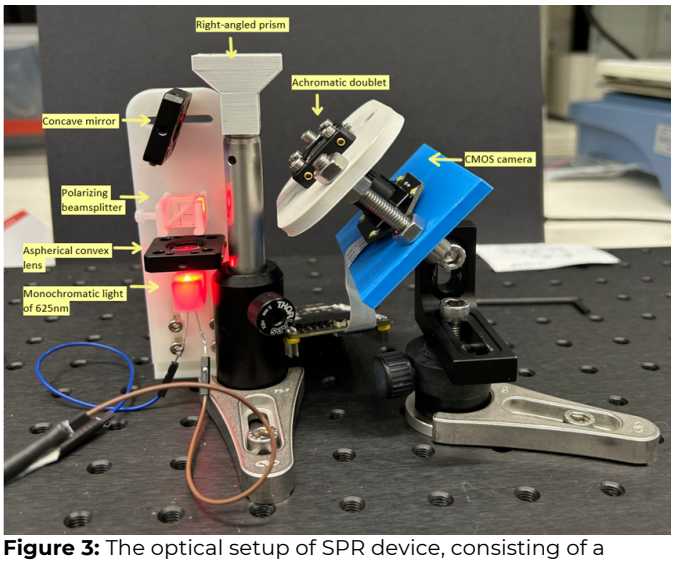

Figure 3: The optical setup of SPR device, consisting of a monochromatic light, aspherical convex lens, polarizing beamsplitter, concave mirror, prism, achromatic doublet and a CMOS camera.

Figure 4: Reader device with integrated SPR setup and LCD screen showing CMOS output and correlated creatinine concentration.

2.3. Cartridge technology

When an ISF sample is applied to the hydrogel surface, it passively migrates to the MIP coated gold film, where creatinine binding produces a measurable refractive index change. Once the measurement is complete, the cartridge initiates an active washing sequence to prepare the sensor for the next reading. Brief electric pulses are applied to disrupt the interaction between creatinine and the MIP cavities, releasing the molecules into the surrounding hydrogel. A sustained voltage, functioning in a manner similar to electrophoresis, then drives the released creatinine toward a positively charged capture membrane located near the cathode. This membrane immobilises the molecules, preventing re binding and avoiding contamination of subsequent measurements. By fully clearing the sensing area, the system maintains accuracy and repeatability across multiple measurement cycles without requiring manual cleaning.

2.4. Reader instrument and user interaction

The reader houses the optical system, cartridge slot, and an LCD display. When a sample is applied, the user sees both the live CMOS image and the calculated creatinine concentration (Figure 4). The display also shows the SPR band movement relative to a fixed calibration line. After measurement, the device automatically initiates the washing process. Once complete, the screen notifies the user that the next sample can be tested.

3. IN award: Biosensor innovation

Looking at current research, we can see that most wearable biosensors use electrochemical sensing. In this project, Surface Plasmon Resonance (SPR) was identified as a promising alternative, offering high sensitivity, label-free detection, and, when combined with Molecularly Imprinted Polymers (MIPs), strong specificity for creatinine and other biomarkers. SPR has seen limited wearable use due to sensitivity to environmental noise and the need for precise optical alignment. By integrating microneedle-based ISF extraction, hydrogel transport, MIP recognition, and a miniaturised SPR system into a single platform, we propose a wearable concept capable of stable, accurate monitoring outside laboratory conditions.

3.1. Wearable sensor

Integrating Surface Plasmon Resonance (SPR) into a wearable device is challenging due to the size of optical assemblies and the technique's sensitivity to mechanical and environmental disturbances. The prism-based SPR system developed in this project measures approximately 6 × 11 cm, achieved by optimising the optical path, selecting low-profile components, and limiting on-board electronics to essential signal processing on a printed circuit board (PCB) (Figure 6). More advanced processing is performed externally after wireless transfer via Bluetooth. For comfort and stability, the sensor is embedded in the fabric of a breathable compression sleeve worn on the upper arm and secured with a Velcro fastening (Figure 5). The skin-like, lightweight material conceals the device, allowing discreet use, continuous skin contact, and reliable measurements in real-world conditions.

Figure 5: Prototype worn on the upper arm.

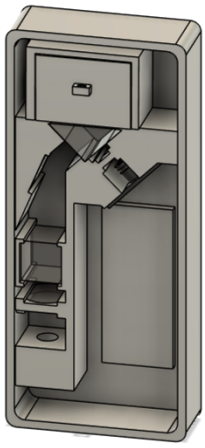

Figure 6: 3D model of the interior structure of the prototype

3.1.1. Technological novelty of wearable sensor

Patient feedback emphasised the need for a design that does not look overtly medical. Embedding the biosensor within the sleeve provides a discreet appearance suitable for

daily wear. The device can be applied by an untrained user and employs hydrogel-based microneedles for pain-free ISF extraction. A rechargeable battery supports all-day operation and is recharged overnight using a wireless charging stand. Data is transferred via Bluetooth to a smartphone for processing, minimising the device's power demands. Continuous sampling is achieved through an electroosmotic washing mechanism that removes bound creatinine from the MIPs and traps it on a positively charged membrane. Both the membrane and microneedle array can be replaced after several days of use.

3.1.2. Technical feasibility of wearable sensor

Integrating Surface Plasmon Resonance (SPR) into a wearable device requires overcoming challenges in miniaturisation, stability, and repeated use. We developed a compact prism-based SPR system measuring about 6 × 11 cm, achieved by optimising the optical path, using low-profile components, and consolidating signal processing on a single PCB. To address its relatively large footprint, the reader is embedded in a breathable compression sleeve worn on the upper arm, providing both stable alignment and a discreet appearance in line with patient feedback.

For continuous use, the bound analyte must be removed without manual cleaning. We implemented an electroosmotic washing mechanism tested with a PVA-PEG-PAAm hydrogel containing fluorescent molecules as a model analyte. Applying 15 V DC for 20 minutes caused a clear reduction in fluorescence, confirming voltage-driven transport and active release from the gel (Figure 7). In the final design, a short voltage pulse would flush creatinine from MIP cavities, with released molecules driven toward a positively charged capture membrane to prevent re-binding. This enables multiple measurements from the same cartridge. Future plate-reader studies will quantify washing efficiency for physiological creatinine levels.

Power modelling shows that the system can run for a full day on a compact 18650-2s Li-ion battery (2600 mAh, 7.2 V) stepped down via a buck converter. Low consumption is achieved by limiting LED operation, performing only basic on-board processing, and transferring small pixel intensity and temperature datasets to a smartphone via Bluetooth for analysis. These results show that miniaturised SPR sensing with electroosmotic washing, efficient power use, and wireless data transfer is feasible in a wearable format. Remaining challenges include maintaining optical alignment during movement and validating

washing performance in real physiological conditions. Fibre optic coupling may further improve robustness in future designs.

These findings indicate that a wearable SPR biosensor with electroosmotic washing, efficient power management, and wireless data transfer is technically feasible. The optical miniaturisation achieved here is sufficient for integration into a wearable sleeve format, while electroosmotic washing offers a viable route to repeated measurements without cartridge replacement. Key remaining challenges include ensuring optical alignment stability during movement and validating washing efficiency for creatinine under real physiological conditions. Fibre optic–based coupling may be explored in future iterations to further reduce size and improve robustness.

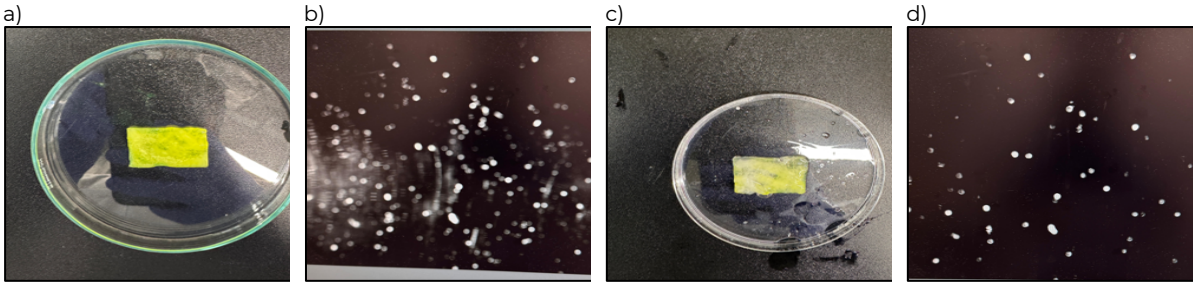

Figure 7: Electric-field driven fluorescein release (a) Image show the gel after soaking with fluorescein sodium salt solution and (b) after DC stimulation in buffer (15 V, ~20 min) between two electrodes. (c) Gel-doc fluorescence confirms strong, uniform dye uptake in the pre-soaked gel and (d) a reduced overall signal after stimulation, consistent with electric-field-driven release of fluorescein from the hydrogel matrix.

3.2. Reliability of sensor output

Surface Plasmon Resonance (SPR) offers very high sensitivity for detecting changes in creatinine concentration, but its precision also makes it sensitive to drift and variability. Even small shifts in the alignment of optical components such as the concave mirror, prism, imaging lens (achromatic doublet), or CMOS sensor can reduce excitation efficiency or cause inaccurate readings. Changes in ambient or local temperature are another significant source of variability. Since the refractive index is inversely proportional to temperature, fluctuations in temperature can cause a measurable shift in the SPR signal that is unrelated to analyte concentration. Addressing this type of spectral drift is essential to maintain accuracy and ensure the results remain consistent with gold standard measurements.

3.2.1. Technological novelty of reliability concept

To ensure that measurements remain accurate in a wearable setting, the sensor integrates multiple stability and calibration features. A two-line optical calibration system introduces fixed reference lines into the optical path, allowing displacement to be measured relative to these lines rather than in absolute terms. This establishes a local coordinate system that corrects for both translation and rotation, ensuring that movement of the SPR signal is attributed to true analyte binding rather than mechanical drift. Environmental monitoring further improves reliability. A temperature sensor detects changes in ambient conditions to distinguish thermal refractive index shifts from biochemical binding events. By combining optical reference lines and environmental sensing, the device applies a multi-layer correction approach. External data processing integrates these inputs to correct for instability, which is especially important for a wearable application where movement and environmental variation are unavoidable.

3.2.2. Technical feasibility of reliability concept

The primary challenge in ensuring the reliability of an SPR–MIP biosensor lies in separating genuine creatinine-induced resonance shifts from environmental and material-related artefacts. Three dominant variability sources were identified: 1) Refractive index changes in the buffer not related to creatinine concentration. 2) Polymer swelling and shrinkage of the MIPs due to temperature variation, altering surface and optical properties. 3) Binding variability between the MIPs and creatinine over time, including potential weakening or loosening of interactions.

To address these challenges, the sensor incorporates an on-board temperature sensing and correction system. The PCB records both the resonance dark spot pixel position and the temperature during every measurement. Calibration is performed over a controlled temperature range of 20–35 °C, producing a temperature–pixel correlation curve. This data yields a correction factor applied in real time to compensate for thermal drift and polymer dimensional changes. Further reliability is achieved through a dual-channel referencing approach. In addition to the MIP sensing area, a reference channel is implemented using either a constant biomarker unaffected by electrical clearing or a non-imprinted polymer (NIP). Since this reference responds only to environmental changes and not creatinine binding, any pixel shifts detected in this channel can be subtracted from the MIP channel data. This allows the system to cancel artefacts arising from buffer refractive index changes, optical component shifts, or mechanical disturbances.

Calibration for creatinine detection is performed by exposing the MIP channel to a series of known creatinine concentrations and recording the corresponding pixel positions of the SPR resonance minimum. An example of the output from this measurement approach is shown in Figure 8, where the dark spot position is identified as the pixel corresponding to the dip in brightness. In this graph, the row index directly relates to the SPR resonance angle shift caused by binding events at the sensing surface. As seen in figure 9a and b there is a shift in in the brightness dip in the row index graphs (from row position 75 to row position 100) The same methodology is applied using the reference channel to ensure that any background shifts (e.g., lens position changes or hydrogel swelling) are mirrored and can be mathematically subtracted from the MIP signal. This referencing method also inherently accounts for gradual changes in the MIP surface caused by repeated measurements, as the reference and sensing layers will degrade in parallel. During validation, a sucrose solution was used as a test analyte to produce known refractive index changes, allowing a calibration curve to be generated for sucrose concentration versus pixel position. This confirmed that the system can accurately track pixel movements and compensate for environmental effects. The resulting calibration process ensures that the sensor output reflects only the true changes in creatinine concentration, with high repeatability and minimal noise. Testing in comparable SPR concepts has shown remarkable accuracy and repeatability, indicating that the proposed reliability strategies are technically feasible and effective for wearable deployment.

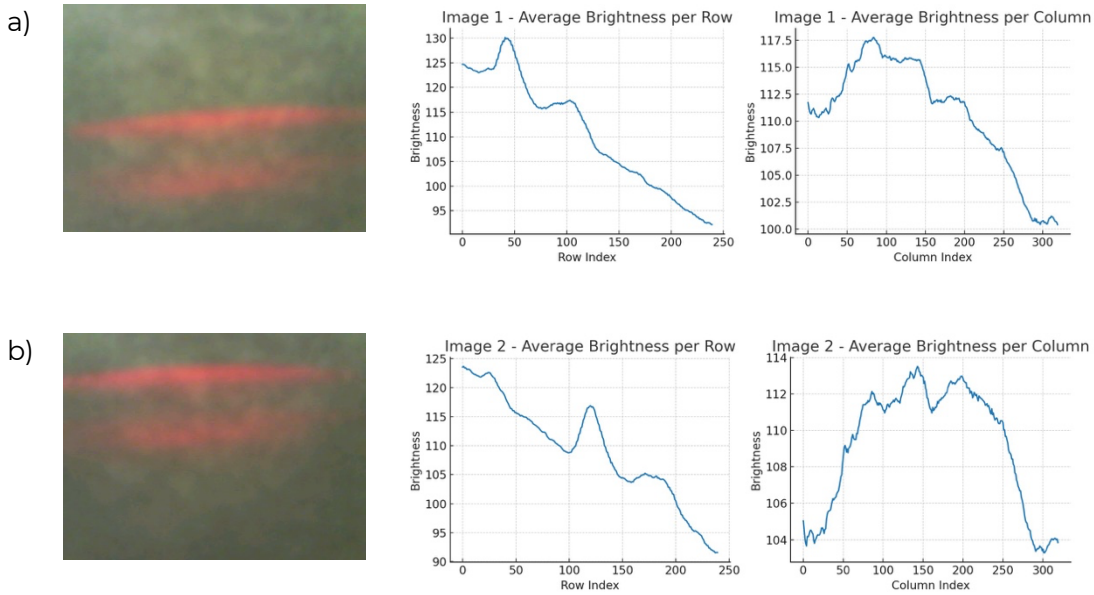

Figure 8: Image and analysis of image recorded by CMOS a) before applying sample b) after applying sample

3.3. Original contributions

3.3.1 Statement from the Team:

The concept for the device was co-developed with patients and clinicians, though no single innovation came from a specific individual or study participant. Key aspects of the technology were conceived and developed by the team, with supervisors Julien Reboud and Chunxiao Hu acting as “critical friends” and advising on areas requiring further investigation. Development and testing were carried out independently, without support from third parties. Technical assistance from University Technicians and researchers in our host groups was limited to equipment access and did not contribute to the scientific concepts. Key novelties, including the SPR based transduction method combined with MIPs for specific creatinine analysis in a wearable format, were developed and tested solely by the team. The project was funded by Kidney Research UK and the University of Glasgow’s Chancellor’s Fund, neither of which were involved in shaping the project ideas.

3.3.2 Statement from Supervisors.

I can confirm that the team have developed their idea completely independently. Some of the team members took a course on biosensors as part of their curriculum, that both Chunxiao and I teach in. The course covers the basics of biosensing and provides examples of different sensor systems and strategies. Members of the team were thus exposed to optical sensors and sandwich assays, along with concepts of microfluidics. They were also aware of the idea of MIPs from last year’s SensUs team. However, they were not exposed to SPR and the MIPs from this year are a different chemistry.

They indeed started their work from scratch, through literature searches of possible strategies and were encouraged by the ease of use of SPR, which to our knowledge has not been integrated with MIPs for creatinine, as key novelty. A second area of innovation lies the use of electrophoresis to reset the MIPs, which again is new in this configuration. Although both supervisors’ groups work on optical biosensors, there is no active project on SPR or MIPs and indeed the team had to purchase the components to build it from scratch. Our role was kept at an advisory level (outlining potential challenges in their strategies), as well as guide access to existing equipment and potentially useful expertise in Glasgow. We are especially proud of the team’s focus on the patients and clinicians’ voices to build a concept that will have maximum impact.


Julien Reboud


Chunxiao Hu


Jonathan Beck


Amelia John

4. TP award: Translation potential

Many biosensor projects begin with a technical solution already in mind. Patients are often consulted at the end, when key decisions are no longer open to change. We chose a different approach. Our aim was to understand the real challenges of living with kidney disease and to develop a solution together with the people most affected by it.

4.1. Customer interviews

We followed the ISO 9241-210 framework for human-centred design through a four-phase process involving interviews, surveys, and focus-group sessions. At each step, participants actively shaped the concept we developed.

Phase 1 **Understand**	Interviews explored personal experiences with kidney monitoring, including pain points, uncertainties, and unmet needs.
Phase 2 **Specify**	Interview data was translated into 241 user requirements, which were ranked for importance using a structured survey among patients.
Phase 3 **Co-Create**	Two design concepts were presented and discussed in a focus group, allowing patients to weigh trade-offs and highlight preferences.
Phase 4 **Validate**	The preferred concept was refined based on feedback and revisited with participants and clinical experts for validation.

This process was supported throughout by the charities Kidney Research UK and the National Kidney Federation, who advised on study design and participant recruitment.

Nine individuals with lived experience of CKD (stages 2 to 4) participated across the four phases, including post-transplant patients and those with experience of AKI or dialysis. Ages ranged from early 30s to late 70s, with a roughly equal gender balance and geographical diversity across the UK.

In parallel, we held structured interviews and feedback sessions with leading clinicians, including: Dr. Ashraf Mikhail (Consultant Nephrologist), Dr. Madhura Fadnis (Paediatric Nephrologist), Dr. Sandip Mitra (Consultant Nephrologist), Dr. Lina Johansson (Clinical Renal Dietitian) and Dr. Hartesh Battu (Primary Care Innovation Lead, NHS West of Scotland Innovation Hub). Patients shared a clear desire for tools that make better use of existing NHS data, offering clear feedback, accessible interfaces, and personalised insights into what their results mean and how to act on them. They also strongly preferred reliable tracking of long-term trends over real-time updates. Constant monitoring was described as emotionally draining and unnecessary. As one participant put it:

"I don't need to be constantly reminded that I am not well... I know that already."

What mattered most was having control over when and how they access information, through a system that is accessible, especially for older or less tech-savvy individuals. To respond to these needs, we developed and tested two concepts: a continuous wearable sensor and a home-based system for on-demand testing. Patients clearly favoured the latter, which became the Kidney Health Hub (Figure ??).

Figure 9: User Interface

Figure 10: 3D-render of the health hub

Figure 11: 3D-render of the collection patch

The wearable device was seen as bulky, emotionally taxing, and too present in daily life. It delivered real-time updates that many found unnecessary or even stressful. In contrast, the Kidney Health Hub gives users a discreet, passive patch worn during the day, which is inserted into a compact home reader in the evening (Figure 11). The system uses SPR analysis to deliver a daily average, allowing for clear trend tracking without continuous monitoring. A simple and personalised app interface (Figure 9) complements the device, making it easy for users to access insights, track trends, and understand their results in a way that fits their lifestyle. The Kidney Health Hub avoids the current limitations of wearable sensors while offering reliable, meaningful, and clinically useful information**.** It is not a compromise, it is a better fit for the people it is meant to help. Through this co-design process, we did not just validate an idea. We created a solution that is aligned with real user needs and ready to be developed further.

4.2. Design of validation study

Unlike many early-stage technologies, the Kidney Health Hub has already undergone formal validation of its core need through a co-design study involving patients, clinicians, and national charities. This process defined the primary user requirements and confirmed that the proposed solution aligns with what patients and healthcare professionals value

most. The next phase focuses on demonstrating that the system delivers these benefits in practice, through technical and clinical validation.

4.2.1 Technical Validation

For technical validation, the goal is to confirm the reliable performance of all core functions in realistic home use scenarios. This will be carried out in collaboration with the Medical Devices Manufacturing Centre (MDMC), which will support the refinement of key functionalities, progress toward scalable manufacturing, and testing under simulated operational conditions. Priority technical areas for further research and testing include:

Step in Interaction Process	**Critical Technical Aspect**	**Proposed Research and Validation Approach**
Patch supply and storage	Stability of hydrogel patches for over a month	Conduct accelerated aging tests under various storage conditions; assess swelling capacity and mechanical integrity over time
Daily patch application	Pain-free application by an untrained user	Usability testing with healthy volunteers and CKD patients using pain scales**,** feedback interviews, and application accuracy checks
Continuous daytime wear	Wearability for 24 hours under varying ambient conditions	Wear trials with volunteers to monitor adhesion, skin irritation, and user-reported comfort across different environments
Patch insertion into the device	Recovery of ISF sample by an untrained user	Simulated use scenarios with target users; measure recovered volume and variability; assess ease of use through observation and interviews
eGFR result	Corellation of extracted sample with average daily creatinine levels	Analytical validation using standard calibration curves, spiked samples, and comparison with clinical assays
Result interpretation	Usability of the touchscreen interface and integration of NHS records	Conduct task-based usability testing on a UI prototype with older users
Long-term performance	Repeatability and durability of the device for daily use	Perform repeated daily testing with the same device over weeks; assess sensor drift, battery life, and calibration needs

4.2.2. Clinical Validation

Clinical validation will be undertaken with nephrologists, NHS clinicians, and regulatory experts to ensure compliance with UK medical device regulations from the outset. This includes securing MHRA and HRA approvals, obtaining study sponsorship, and establishing quality and risk management processes in line with ISO 13485 and ISO 14971. Digital components will be assessed under DTAC criteria, and NHS adoption pathways such as the “innovator passport” will be explored to enable faster deployment following successful trials. NHS clinicians will lead protocol development, patient safety oversight, and interpretation of results to ensure the study meets both regulatory and clinical expectations. The pilot study (Figure 12) will run in three sequential phases over one year, beginning with post-transplant patients, which is the group most likely to benefit from early detection of kidney function deterioration. This could potentially be expanded to CKD stage 3 patients. The proposed study will run in three phases over one year:

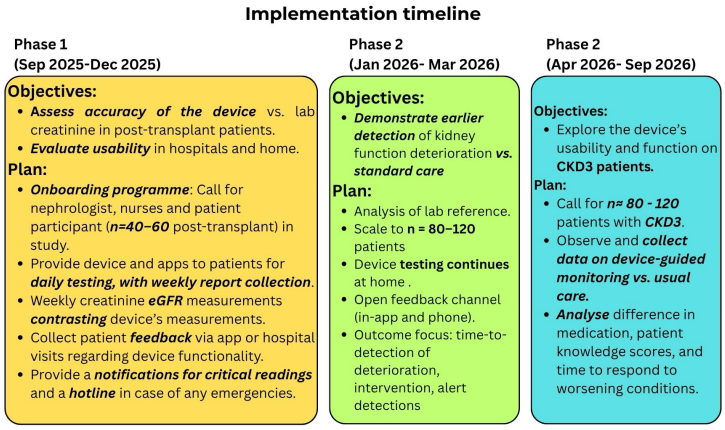

Figure 12: Clinical Validation Study

Phase 1: Accuracy and usability testing

The primary objective is to compare the device's creatinine measurements directly with current laboratory blood tests. Participants will receive in-hospital training before taking the device home. They will collect daily samples, attend weekly hospital visits for reference tests, and provide weekly usability feedback through surveys and interviews. Key indicators will include measurement accuracy versus laboratory results, ease of use, clarity of instructions, patient satisfaction, and number and type of reported issues.

Phase 2: Earlier detection of kidney deterioration and improved health outcomes

The focus shifts to assessing whether the device can detect kidney function decline earlier than standard care, enabling faster clinical intervention. Participants will continue home monitoring with regular hospital reference tests. KPIs will include the time from detection to clinical response, the number of early interventions triggered, and patient engagement metrics such as adherence rates and Net Promoter Scores.

Phase 3: Test broader applicability

Following refinement from earlier phases, the study may expand to include CKD stage 3 patients. The objective is to evaluate whether the device can improve understanding of kidney health and support more timely medication adjustments. Indicators will include patient-reported confidence in managing their condition, frequency of medication changes informed by device readings, and comparison of health outcomes with a control group receiving standard care.

Upon completion of the pilot, results will be analysed to determine both clinical and practical viability. If outcomes meet predefined accuracy, usability, and impact thresholds, the project will progress to larger-scale trials and explore commercialisation in line with UKCA or CE marking requirements and NHS adoption processes.

5. Team and support

5.1. Contributions of the team members

Name	Contributions
Aayushi Mahesh Kasture	Member of the Detection and Transduction team; In charge of hydrogel formulation and testing; assessed regulatory landscape for commercial translation.
Amelia John	Secretary of the student society; led detection and transduction team; designed and developed SPR test setup; supported co-design study.
Baitki Shilla	Member of Healthcare integration team. Developed user interface for biosensor.
Cong Liu	Member of the system integration team. Developed code for image and data processing.
Jana Alimam Alhusseini	Member of the Detection and Transduction team. Developed and carried out tests on hydrogels.
Jiaqi Fan	Member of the system integration team. Manufactured PCB board for biosensor.
Jonathan Beck	Captain of GLASense; led Healthcare Integration team and co-design study; conducted patient interviews; developed CAD models for prototype, secured sponsors.
Morris Mcdiarmid	Led system integration team, developed SPR setup and CAD models.
Shriraghav Sivakumar	Member of the Detection and Transduction team; Proposed technical suggestions on SPR; helped develop SPR setup.
Siddhesh Pranav Jadhav	Member of the Detection and Transduction team; Developed hydrogel formulation; carried out diffusion tests.
Vivienne Awumee	Member of the System Integration team. Helped design and develop SPR setup as well as CAD models.

5.2. People who have given support

Julien Reboud	Team supervisor offering guidance and support
Chunxiao Hu	Team supervisor offering guidance and support

5.3. Sponsors and partners

Kidney Research UK	Funded the team and offered advice and support in the co-design study
National Kidney Federation	Offered advice and support in the co-design study
Popham Kidney Support	Offered advice and helped with connecting us with clinicians
University of Glasgow	Funded the team through the Chancellors Fund

6. Final remarks

This work demonstrates the feasibility of a miniaturised, calibration-stabilised SPR–MIP biosensor with active electrophoretic washing, enabling continuous interstitial fluid analysis in a discreet wearable format. By combining high-sensitivity optics, molecular selectivity, and patient-centred design, we developed a system that is both technically robust and clinically relevant. Co-design with patients, clinicians, and stakeholders led to the Kidney Health Hub: a discreet, passive solution separating sampling and sensing while maintaining accuracy and usability. We have defined a clear validation pathway, starting with post-transplant patients, to confirm diagnostic accuracy, assess usability, and evaluate its potential for earlier detection of kidney decline. With technical, clinical, and regulatory steps mapped, this innovation is positioned for large-scale trials and potential NHS adoption, offering earlier intervention, improved outcomes, and reduced healthcare costs.

7. References

Alizadeh, T., & Mousavi, Z. (2022). Molecularly imprinted polymer specific to creatinine complex with copper(II) ions for voltammetric determination of creatinine. Microchimica Acta, 189(10). https://doi.org/10.1007/s00604-022-05470-8

Aykut Arif Topçu, Erdoğan Özgür, Fatma Yılmaz, Nilay Bereli, & Adil Denizli. (2019). Real time monitoring and label free creatinine detection with artificial receptors. Materials Science and Engineering B, 244, 6–11. https://doi.org/10.1016/j.mseb.2019.04.018

Bahar Bankoğlu Yola, Neslihan Özdemir, & Mehmet Lütfi Yola. (2024). A Review Study on Molecularly Imprinting Surface Plasmon Resonance Sensors for Food Analysis. Biosensors, 14(12), 571–571. https://doi.org/10.3390/bios14120571

Butt, M. A. (2025). Surface Plasmon Resonance-Based Biodetection Systems: Principles, Progress and Applications—A Comprehensive Review. Biosensors, 15(1), 35–35. https://doi.org/10.3390/bios15010035

Culver, H. R., Clegg, J. R., & Peppas, N. A. (2017). Analyte-Responsive Hydrogels: Intelligent Materials for Biosensing and Drug Delivery. Accounts of Chemical Research, 50(2), 170–178. https://doi.org/10.1021/acs.accounts.6b00533

Ghosh, S., Kumar, N., & Chattopadhyay, S. (2024). ELECTRICALLY CONDUCTIVE “SMART” HYDROGELS FOR ON-DEMAND DRUG DELIVERY. Asian Journal of Pharmaceutical Sciences, 101007. https://doi.org/10.1016/j.ajps.2024.101007

Huang, S.-C., Lee, G.-B., Chien, F.-C., Chen, S.-J., Chen, W.-J., & Yang, M.-C. (2006). A microfluidic system with integrated molecular imprinting polymer films for surface plasmon resonance detection. Journal of Micromechanics and Microengineering, 16(7), 1251–1257. https://doi.org/10.1088/0960-1317/16/7/019

Koetting, M. C., Peters, J. T., Steichen, S. D., & Peppas, N. A. (2015). Stimulus-responsive hydrogels: Theory, modern advances, and applications. Materials Science and Engineering: R: Reports, 93, 1–49. https://doi.org/10.1016/j.mser.2015.04.001

Medicines and Healthcare Products Regulatory Agency. (2024). Medical Devices Regulations: Routes to market and in vitro diagnostic devices Consultation. https://assets.publishing.service.gov.uk/media/672cf23c0207c4664564ce45/Medical_Devices_Consultation_November_2024.pdf

National Health Service . (2025). Your guide to innovation in the NHS. Innovation Service. https://innovation.nhs.uk/innovation-guides/

Peppas, N. A., & Khare, A. R. (1993). Preparation, structure and diffusional behavior of hydrogels in controlled release. Advanced Drug Delivery Reviews, 11(1-2), 1–35. https://doi.org/10.1016/0169-409x(93)90025-y

Saylan, Y., Akgönüllü, S., Yavuz, H., Ünal, S., & Denizli, A. (2019). Molecularly Imprinted Polymer Based Sensors for Medical Applications. Sensors, 19(6), 1279. https://doi.org/10.3390/s19061279

Silva, A. T., Figueiredo, R., Azenha, M., Jorge, P. A. S., Pereira, C. M., & Ribeiro, J. A. (2023). Imprinted Hydrogel Nanoparticles for Protein Biosensing: A Review. ACS Sensors, 8(8), 2898–2920. https://doi.org/10.1021/acssensors.3c01010

Sullivan, M. V., Sakshi Nanalal, Dean, B. E., & Turner, N. W. (2023). Molecularly imprinted polymer hydrogel sheets with metalloporphyrin-incorporated molecular recognition sites for protein capture. Talanta, 266, 125083–125083. https://doi.org/10.1016/j.talanta.2023.125083

Thang , H. N., Chien, T., & Cuong, D. X. (2023). Polymer-Based Hydrogels Applied in Drug Delivery: An Overview. Gels, 9(7), 523–523. https://doi.org/10.3390/gels9070523

THE DEPARTMENT OF HEALTH AND SOCIAL CARE. (2021). Notice of Publication 0034/21: Designated Standards - Medical Devices.

Tripta Kamra, Zhou, T., Montelius, L., Joachim Schnadt, & Ye, L. (2015). Implementation of molecularly imprinted polymer beads for surface enhanced Raman detection. Analytical Chemistry, 87(10), 5056–5061. https://doi.org/10.1021/acs.analchem.5b00774

Wu, T., Shao, Y., Wang, Y., Cao, S., Cao, W., Zhang, F., Liao, C., He, J., Huang, Y., Hou, M., & Wang, Y. (2017). Surface plasmon resonance biosensor based on gold-coated side-polished hexagonal structure photonic crystal fiber. Optics Express, 25(17), 20313–20313. https://doi.org/10.1364/oe.25.020313

Yeasmin, S., & Cheng, L.-J. (2024). Emerging trends in functional molecularly imprinted polymers for electrochemical detection of biomarkers. Biomicrofluidics, 18(3). https://doi.org/10.1063/5.0194200