Team Results Document

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1. Abstract

Cornell SensTech has developed a novel detection method to monitor creatinine levels in interstitial fluid (ISF) to address the unmet need of inaccessible monitoring options for those with acute kidney injury (AKI). Many instances of AKI occur in outpatient or home settings, especially among older adults in rural areas, where early signs frequently go undetected. This home-based solution enables proactive kidney monitoring and empowers timely clinical intervention. The core sensing element is an innovative Creatinine-Specific Nanocomposite (CSN) composed of a polypyrrole composite material embedded with Pd/Cu_2O nanoparticles. The CSN relies on the highly specific interaction between copper (I) oxide and creatinine to create a copper-creatinine complex that is recorded using a three-electrode system. The movement of ISF through the sensor is controlled via a fluidic pump that transfers the sample onto a screen-printed electrode fitted with the nanocomposite. As ISF passes through the channel, creatinine binds to the CSN. This interaction creates a distinct peak which appears at the potential where creatinine undergoes a rapid electrochemical reaction as voltage is applied via cyclic voltammetry. This signal is translated into a quantified creatinine concentration, which is then transmitted through Bluetooth to an application for immediate patient access.

2. Biosensor System

2.1 Molecular Recognition

The design of Cornell SensTech's innovative biosensor leverages a Creatinine Specific Nanocomposite (CSN) applied in tandem with a three-electrode system for the selective detection of creatinine in interstitial fluid (ISF). Unlike traditional biorecognition elements such as antibodies, aptamers, or enzymes, the CSN capitalizes on the high catalytic performance of copper (I) oxide to produce a measurable signal in the presence of creatinine [1]. In combination with palladium nanoparticles designed to provide an appropriate platform enhancing the surface area and conducting routes of the Cu_2O, the nanoparticles are embedded within a supporting polypyrrole structural matrix to enhance the conducting capabilities of the overall material [1].

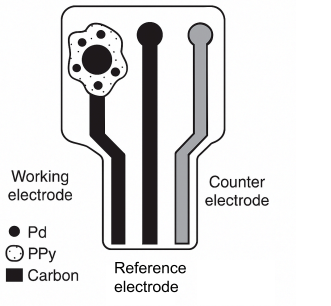

Figure 1: Preliminary schematic of the CSN.

The electrochemical process we explored in our testing consisted of utilizing a conventional three-electrode system with a carbon as the working electrode, a carbon counter electrode, and a Ag/AgCl reference electrode. The functional sensing layer is composed of a palladium/cuprous oxide/polypyrrole ($Pd/Cu_2O/PPy$) nanocomposite [1]. Here, palladium is used in the form of nanoparticles to enhance the electrocatalytic activity by assisting electron transfers. Cuprous oxide (Cu_2O) is a p-type semiconductor whose surface copper sites strongly complex creatinine, enabling selective electrochemical detection [2] (Figure 2). In the $Pd/Cu_2O/PPy$ nanocomposite, Cu_2O nanoparticles are embedded within a polypyrrole (PPy) matrix, which provides high electrical conductivity, mechanical stability, and a porous structure for efficient analyte access. The resulting $Pd/Cu_2O/PPy$ nanocomposite is a dark, powder-like material that is easily dispersible in solvents such as ethanol onto an electrode's surface, allowing for uniform deposition. When transitioning this technology into a piece of wearable tech, the three-electrode system was implemented through a screen-printed electrode (SPE) to allow for a more easily replicable and simplistic design of the overall sensor (Figure 1).

$$Cu^{2+} + \text{creatinine} + H_2O \rightarrow Cu + \text{oxime creatinine} + 2H^+$$
Figure 2: Reaction between oxidized copper and creatinine

Cyclic voltammetry is then performed with this nanocomposite present within a potential window at a scan rate of 70 mV/s to firstly establish the baseline electrochemical response before introducing the creatinine. The CSN nanocomposite particles are dissolved in ethanol before being dropped onto a prepared screen-printed electrode (SPE), forming the sensing mechanism of the sensor [3]. Following initial testing, we improved to a system incorporating a SPE, microfluidic channel, and pump to efficiently transfer and detect creatinine levels in the ISF. A potentiostat is connected to the SPE, allowing changes in current to be measured and translated into the creatinine concentration in the sample.

2.2 Physical Transduction

During cyclic voltammetry, a potentiostat applies a voltage that sweeps forward and backward across a set range while simultaneously measuring current [4]. When the applied potential reaches the redox potential of the copper-creatinine complex, a peak is observed. The position of the peak along the voltage axis reflects the electrochemical characteristics of the complex [5]. In preliminary testing, these

voltages where the peak current occurs are recorded for known creatinine concentrations to generate a calibration curve, which is then fitted with an equation of best fit [6]. For actual measurements, ISF containing creatinine produces a CV peak whose voltage producing the peak height is matched against the calibration curve to determine the creatinine concentration (Figure 3). The result can be directly processed and transmitted for display in real time.

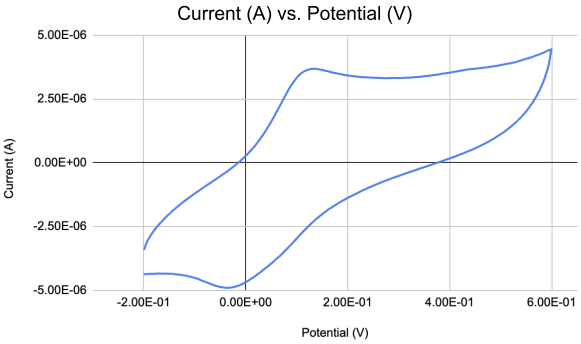

Figure 3: Cyclic Voltammetry graph for PBS + Creatinine solution; performed to verify that the interaction was feasible

2.3 Cartridge Technology

Our biosensing system is designed to have a vertically stacked cartridge system for continuous creatinine monitoring using a CSN-based sensing system integrated into a 3D printed microfluidic channel [7]. The ISF from a sample is drawn using a continuous microfluidic pump [8]. This microcontroller-controlled pump consists of a DC peristaltic motor with tubing attached. The tubing will be set up such that one end touches a reservoir drawing ISF into the channel, while on the other end another tube draws ISF out of the channel back into the reservoir enabling continuous and controlled deposition and suction of the interstitial fluid (ISF). For continuous monitoring for relatively small molecules like creatinine, taking into account current signal stability, dimensions of the tubing, and redox reaction time ranges from 10-50µL/min [9]. The device will have a flow rate of approximately 10 µL/min, giving the ISF one minute to pass over the sensor and produce a reading. The ISF is then directed through the microfluidic channel where it interacts with the CSN coated on the working electrode of the SPE system. This arrangement allows creatinine to selectively bind to the CSN on the working electrode surface, producing a current signal measured by the potentiostat. The system monitors the redox response generated by creatinine over time using cyclic voltammetry, enabling quantitative electrochemical detection (Figure 4).

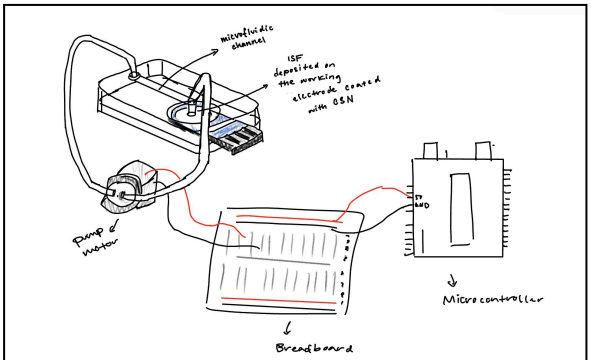

Figure 4: Screen Printed Electrode (SPE) aligned under a microfluidic channel, connected to tubing for fluid flow driven by a pump motor. The SPE is wired to a breadboard for signal processing, enabling real-time electrochemical sensing. A schematic hand-drawn using Notability.

2.4 Reader Instrument and User Interaction

The patient begins by applying the patch to a dry area of the skin on the upper arm. The CreatConnect app continuously monitors creatinine levels in real time through the microneedle patch, which draws interstitial fluid (ISF) across the CSN-coated sensing surface at programmed intervals and measures an aptitude through CV. The app's home screen features a live updating threshold bar that changes instantly as new readings are processed, showing whether the user's creatinine level is in the Low, Normal, or High range [See Appendix 1, 4, 6]. A real-time graph displays fluctuations over time, allowing patients to track trends throughout the day [See Appendix 2]. If the system detects a shift outside the user's normal baseline, the app immediately issues a visual alert and recommends follow-up with a healthcare provider. The "History Log" section lists the user's average creatinine level per day with the date, time, creatinine value, and status in an easy-to-read format [See Appendix 3]. In the case of critically abnormal readings, a "Call a Doctor" button appears for rapid response. The "Health Info" section stores broader health metrics, such as age, sex, weight, and relevant medical conditions, enabling CreatConnect to deliver personalized, context-aware health insights based on both creatinine trends and the patient's overall health profile [See Appendix 1, 4, 5].

3. Biosensor Innovation

3.1 Wearable Sensor

The wearable creatinine biosensor is envisioned as a long-term, continuous monitoring patch that works seamlessly with an online application, CreatConnect, to provide patients and doctors with clear, real-time updates on kidney function. Measuring 40 mm × 25 mm with an overall thickness of about 5–6 mm, the patch has a sterile, replaceable cartridge containing a microneedle array, an interstitial fluid (ISF) reservoir, and a waste layer [11]. The microneedles, measuring theoretically around 250–500 µm in length, are designed to penetrate just deep enough to access ISF while avoiding pain receptors and blood vessels, ensuring a painless and consistent fluid draw [12]. ISF is channeled over a miniaturized screen-printed electrode (SPE) connected to a piezo micro-pump, which moves fluid into the waste layer after measurement [10][12][13]. The replaceable cartridge is changed daily to maintain sterility and measurement accuracy, while the electronics, flexible PCB (about 20 × 12 mm) with vertically stacked potentiostat and microcontroller, and thin coin cell battery remain reusable for several days to two weeks, depending on sampling frequency and wireless transmission intervals [10][12][13]. Data is sent via Bluetooth to the CreatConnect app, where it is processed and displayed in a user-friendly format. With the possibility of refinement to the microfluidic and electronic components, the system could be miniaturized to 20 × 25 mm without compromising reproducibility [10]. This makes the device more comfortable for placement on well-perfused areas such as the upper arm or abdomen [10]. These additional features and adjustments ensure enhanced hygiene, comfort, and reliable continuous kidney health monitoring.

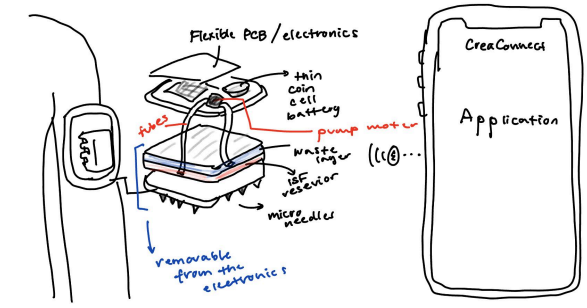

Figure 5: A wearable patch is attached to the human. This patch consists of a microneedle, Flexible PCB, battery, piezo micropump, SPE reservoir and a waste layer in order to safely monitor a person's creatinine levels. These components are replaceable with the data being transmitted to a app.

3.1.1 Technological Novelty of Wearable Sensor

The novelty of Cornell SensTech's biosensor lies in its integration of (1) microneedle-based ISF sampling, (2) piezoelectric microfluidics, and (3) a nanocomposite sensing surface into a wearable patch for real-time creatinine monitoring. The small size of the microneedles allows them to painlessly extract interstitial fluid, enabling continuous, non-invasive monitoring without blood draws. A miniaturized piezoelectric pump actively drives ISF through the sensing chamber, offering precise, low-power fluid control, which is an advancement over passive systems. Additionally, the base of the sensor uses a Pd/Cu_2O/polypyrrole (PPy) nanocomposite that is electropolymerized in the presence of creatinine to create creatinine-specific nanocavities. This creatinine-specific nanocomposite system enables continuous and dynamic detection through a fully integrated microfluidic-electrode interface (Figure 5). This is different from traditional nanocomposite sensors that function in static, single-use conditions.

After creatinine binds to the creatinine-specific nanocavities, the PCB contains the function necessary for measurement of concentration. ISF is then continuously collected through the microneedle array and pumped via a miniaturized piezoelectric pump across the three-electrode setup (working, counter, and reference), all embedded within the patch. Changes in the voltage where the current peak occurs during cyclic voltammetry (CV) reflect creatinine concentration and are processed by an ultra-low-power potentiostat circuit, making the platform suitable for wearable deployment. Results are sent in real time to a mobile app, offering patients and clinicians instant access to creatinine levels without blood draws or lab visits. This system marks a fundamentally new approach to continuous

kidney function monitoring, combining portability, reusability, and patient usability in user-friendly format.

3.1.2 Technical Feasibility of Wearable Sensor

Microneedle Patch

Microneedles fabricated from biocompatible polymers, can penetrate the stratum corneum without reaching pain receptors, allowing for painless, repeated sampling [13]. For this biosensor, hollow microneedles can be integrated directly into the patch to enable passive or active extraction of ISF. These microneedles can interface with microfluidic channels embedded in the patch, enabling continuous delivery of ISF to the electrode chamber. Manufacturing processes such as photolithography, laser cutting, or micromolding can produce uniform microneedle arrays at scale, while adhesion to skin can be maintained with medical-grade adhesives [14]. The feasibility is further enhanced by commercially available microneedle designs that have already been used in drug delivery and biomarker sampling applications, showing good compatibility with wearable devices [14].

Miniature piezoelectric pump

The wearable miniature piezoelectric pump operates through a piezoelectric actuator that changes shape when an electric voltage is applied. This actuator is a thin, flexible membrane, often made from lead zirconate titanate (PZT) ceramics or polyvinylidene fluoride (PVDF) polymers [15]. When the membrane bends or vibrates, it generates pressure pulses within a microfluidic chamber, pushing fluid forward through one-way valves to maintain a unidirectional flow. PZT ceramics, with their high piezoelectric coefficient, produce greater strain and larger displacements per unit voltage, enabling efficient pumping at lower power levels; however, they present as a brittle biomaterial. PVDF, on the other hand, provides flexibility and durability with a lower displacement of the interstitial fluid (ISF) [15]. The advantage of a high piezoelectric coefficient lies in its ability to produce significant movement with minimal voltage, allowing the pump to reach flow rates around 30 μL/min. This helps overcome resistance in microchannels or skin interfaces, while keeping energy consumption low [16].

Experimental studies have demonstrated that pumps using flexible piezoelectric copolymer films can achieve flow rates up to 25 μL/min at 60 Hz and 60 V peak-to-peak voltage, with performance enhanced by using a heating treatment process (annealing) that improve crystallinity and membrane deformation [15]. Other designs have achieved approximately 30 μL/min with power consumption between 10–100 mW at around 100 Hz, showing potential applicability in interstitial fluid sampling [16]. More advanced configurations, including dual-inlet valve systems, have reported flow rates close to 33 mL/min under similar operating conditions, highlighting scalability for a variety of applications [17].

From a feasibility perspective, advances in high-performance piezoelectric materials and microfabrication techniques have improved both efficiency and durability without major degradation of the pump. However, some technical challenges remain, including optimizing valve reliability, ensuring long-term stability of thin membranes under the cyclic loading, and integrating the necessary drive electronics into a compact patch. Both experimental data and simulation models support the conclusion that miniature piezoelectric pumps are technically feasible for the patch and the electrical components inside as there is ongoing research to further enhance performance and reliability.

Mechanism of Sensing: Creatine-Specific Nanocomposite and Low-Power Potentiostat

The wearable biosensor functions by integrating a CSN film directly onto the working electrode of a three-electrode electrochemical cell. The CSN is electropolymerized in the presence of creatinine, creating binding sites that match the analyte's size, geometry, and chemical properties. Following template removal, copper(I) ions are introduced to enable electrochemical detection through stable Cu-creatinine complex formation [10]. This complex exhibits redox activity, which is detected using

cyclic voltammetry (CV) with a screen-printed electrode consisting of a carbon working electrode, an Ag/AgCl reference electrode, and a carbon counter electrode. In operation, interstitial fluid (ISF) flows through a microfluidic channel over the CSN-modified surface and interacts with the Cu(II)-containing electrolyte. A miniature potentiostat applies voltage, and the resulting current, which is proportional to creatinine concentration, is recorded. The technical feasibility of this system is supported by both theoretical calculations and literature precedent. Using the Randles-Ševčík relation, a 100 μM creatinine concentration, representative of physiological ISF levels, is predicted to yield a peak current of approximately 1.9 μA for a 0.07 cm^2 electrode at a scan rate of 0.10 V s^{-1}, assuming a diffusion coefficient of 1×10^{-5} cm^2 s^{-1} [12]. This current is well within the detection range of miniature wearable potentiostats. Simulated CV responses under these conditions further support a distinct redox peak corresponding to Cu-creatinine complexation (See *Figure 3*). Prior studies have demonstrated the reliable electrochemical detection of Cu-creatinine complexes at low micromolar levels without enzymatic amplification, confirming the viability of our transduction approach [10]. Furthermore, recent work on electrode-integrated CSN films has shown that low-voltage electrical stimulation can repeatedly release bound analytes without degrading binding performance [5], validating our refresh strategy for continuous operation.

3.2 Reliability of Sensor Output

Cyclic Voltammetry

To ensure reliable measurements comparable to gold-standard techniques, we use cyclic voltammetry (CV) as both a detection and internal validation method. The key innovation lies in modeling the CV response over time by capturing both peak intensity and potential shifts in order to tell apart from true changes in creatinine concentration. Our three-electrode setup (working, reference, and counter) stabilizes measurements by mitigating noise from motion artifacts, temperature fluctuations, and non-specific electrochemical reactions [18]. The primary sources of variability expected in our wearable biosensor include biofouling, mechanical deformation due to user movement, and changes in skin-electrode impedance. To reduce these effects, we incorporated a CSN formulation resistant to nonspecific binding and designed a flexible electrode interface that minimizes contact variability. We are also developing a continuous self-calibration algorithm that cross-references peak ratios with temporal signal patterns to correct for signal drift in real time. This algorithm is trained on data collected under controlled conditions, ensuring that the biosensor provides accurate and reproducible measurements across different users and environments.

Accuracy Limitations and Future Feasibility

Primary sources of inaccuracy include motion artifacts, temperature shifts, and changes in skin contact. To reduce these effects, we are integrating bandpass frequency filters between the electrode system and the analog to digital converter. These filters remove noise outside the expected signal range caused by movement or environmental changes. We are also incorporating a reference channel that does not interact with creatinine to allow real-time baseline correction. Combined with our self-calibrating software, these features improve signal stability and ensure reliable measurements consistent with gold-standard methods.

To maintain long-term accuracy, the biosensor will include an algorithm that continuously evaluates signal quality by monitoring peak shape, baseline stability, and reference channel consistency. If signal reliability drops below a set threshold, the companion app can prompt users to recalibrate, clean, or replace the patch to restore optimal performance. A monthly kit would be provided to include cleaning tools and spare electrodes, with replacements sent regularly to prevent sensor degradation to reduce variability in the creatinine levels over time.

3.2.1 Technological Novelty of Reliability Concept

Molecular Recognition and Physical Transduction

The sensor detects creatinine using a Pd/Cu_2O/PPy nanocomposite, in which Cu_2O nanoparticles are embedded within a polypyrrole (PPy) matrix, providing high electrical conductivity, mechanical stability, and a porous structure for efficient analyte access. The CSN interaction with creatinine produces a distinct redox response, which is amplified by the high conductivity of the PPy scaffold and catalytic synergy with palladium. This design enables real-time, non-enzymatic monitoring of creatinine directly in ISF, offering greater stability and miniaturization in comparison to other traditional methods.

The system uses a novel electrochemical transduction mechanism optimized for continuous interstitial fluid monitoring, built around a low-impedance three-electrode configuration and cyclic voltammetry (CV). Unlike fixed-potential methods like amperometry or potentiometry, CV applies a sweeping voltage that captures both oxidation and reduction events, generating distinct current peaks directly related to analyte concentration. This enhances specificity, sensitivity, and resistance to signal interference, especially when paired with a CSN layer on the working electrode. The Arduino readout converts these responses into quantifiable digital signals, enabling real-time, low-power analysis with signal linearity across clinically relevant ranges. This offers superior resolution, response speed, and robustness compared to traditional optical or enzymatic sensors.

User Interaction

The CreatConnect mobile app will be able to deliver real-time creatinine modeling at a 3-hour interval for the user. The app will use a built-in machine learning algorithm that detects anomalies by comparing each reading to the user's personal baseline and historical trends, providing alerts to the user when results deviate from expected patterns. By incorporating individual health information such as height, age, weight, past medical conditions, and current medications, CreatConnect generates a personalized breakdown of what their creatinine level means that is specific for the user [See Appendix 5]. A dynamic, color-coded threshold bar visually displays the user's unique healthy range, and every reading is automatically logged for trend tracking and easy sharing with healthcare providers [See Appendix 1 and Appendix 3]. This combination of advanced biosensing, AI-driven insights, and personalized health analytics makes CreatConnect a novel and intuitive tool for kidney health management. In the future, CreatConnect could feature an AI-powered chatbox that explains readings in simple, personalized terms, provides lifestyle recommendations, tracks symptom patterns, answers kidney health questions, and prepares summary reports for doctors, giving users a clear understanding of their results before seeking medical advice.

3.2.2 Technical Feasibility of Reliability Concept

To ensure consistent and accurate creatinine detection, our sensor incorporates a nanocomposite sensing layer engineered for thermal stability, chemical durability, and molecular selectivity. This material is specifically designed to function in interstitial fluid and bind creatinine with high specificity. To test its performance, we conducted electrochemical validation using phosphate-buffered saline (PBS) solutions with and without creatinine. As shown in Figure 6 (Appendix 7), the cyclic voltammetry (CV) curve for the creatinine-containing sample (left) displays clear redox peaks, while the control sample with only PBS (right) shows a flatter, less defined response. These peak differences confirm that the sensor's output is driven by specific molecular interactions with creatinine rather than background interference. This validation demonstrates the sensor's sensitivity and selectivity, supporting its technical feasibility for continuous, real-time biosensing in wearable applications.

3.3 Original contributions

3.3.1 Team Captains

The team is developing a biosensor inspired by CSNs and previous research on interactions between copper (I) oxide and creatinine. With the help of the coaches, the team also considered alternate routes. For example, the team explored continuing last year's biosensor based on DNA aptamers, but the DNA sequence was not specific enough to bind to the creatinine. The previous OIRD system proved it could not detect small differences on the glass slides when the DNA did not properly bind. The team also explored using a fluorescent probe specific to creatinine with detection of creatinine via a luminescence chip, but there was a large challenge of non-specific binding. Due to this, the team decided to move forward with CSNs, using a to create a copper-creatinine complex and a three-electrode system. The team built and tested CSNs with guidance from their coaches. The team also designed a prototype visual of a software display of what the results would look like for patients using the biosensor. The team sees potential in this unique method that combines CSNs, cyclic voltametry, and a user-friendly mobile application.

Alexander Harris (SensTech Team Captain)

Alice Wei (SensTech Team Captain)

3.3.2 Team Supervisor

The team met on a regular basis to discuss various sensor ideas that they would test. The decision was made to focus on the use of creatinine-specific nanocomposites, since they are inexpensive to create and easy to work with. The team found literature reviews and publications that showed the procedure for a hybrid chip procedure, and we modified the CSN layers: electrodes, microfluidic flow channel system, and data acquisition transduction system. Last year we tested a specific DNA aptamer sequence bound to glass slides using a NHS-PEG linker, but never saw a reproducible signal change that correlated with creatinine concentrations. The detection method we are investigating uses cyclic voltammetry to gather the potential of the electrode within the range of the competition creatinine levels and measure the resulting current. Initial CV results showed trouble in creatinine binding the to pyrrole grafted electrode, so the team changed the CSN from pyrrole to a pyrrole copper complex material, producing better results to generate a calibration curve.

Warren Zipfel (Team Supervisor)

4. Translation Potential

4.1 Introduction

Joanna Commander

Joanna Commander is a strong potential customer for an at home creatinine biosensor from Long Island, New York. At 77, with a history of heart surgeries, congenital heart defect, diabetes, and AKI, she fits a high-risk profile. Her sister's death from renal failure adds emotional motivation, and her proactive health habits (daily glucose finger pricks, regular blood work) suggest strong adherence to monitoring tools. Through our Zoom interview we were able to learn more about her routines, concerns, and openness to technology. More specifically, we learned about her high willingness to use a biosensor app, as she has a strong trust in health tech. She also has a desire for real-time, actionable data due to her deep personal investment in her own kidney health.

Harold Thompson

Harold Thompson represents a tech-aware, high-risk demographic for continuous kidney monitoring. At 79, he is living in an elderly home in rural New York, with stage 3 AKI, diabetes complications, and a history of AKI. He shared that his health care is "a lot to keep track of," with monthly lab work and regular specialist appointments. Harold also mentioned that kidney disease runs in his family, which adds to his motivation to stay ahead of complications. In our interview, he said he already uses a smartwatch to track steps and heart rate and liked the idea of connecting a kidney-monitoring sensor to something he's already comfortable with. He saw the device as something that could fit into his existing routine and help him catch problems before they escalate.

Jeremiah Brooks

Jeremiah Brooks is a recovering AKI patient from rural Pennsylvania who values simplicity in health tools. At 68, after a major surgery, his creatinine spiked significantly, leading to weekly labs and frequent visits to his nephrologist. In our interview, he expressed a preference for a device that minimizes manual input and integrates with physician monitoring. Jeremiah's limited tech familiarity means he would greatly benefit from a biosensor with large, clear, and easy-to-read alerts. His primary motivation is to avoid future hospitalizations and regain a sense of confidence and control over his health. He desires a tool that simplifies his care routine rather than complicating it, allowing him to focus on recovery and living his life without constant worry about his creatinine levels.

Dr. Sri Lekha Tummalapalli

Patients are most susceptible to AKI after major surgeries including kidney transplants. As leading nephrologist Dr. Sri Lekha Tummalapalli from Weill Cornell Medicine discussed with us in an interview, kidney transplant recipients as well as acutely ill and late-stage AKI patients, particularly those with uncontrolled diabetes and diabetic retinopathy, are among the highest-risk groups for AKI and would benefit greatly from proactive monitoring. With approximately 200,000 transplant recipients in America, many of whom are hospitalized twice a year, preventing one admission could save around $10,000 per patient. Episodes of diarrhea or dehydration often require urgent testing, yet logistical delays in traveling and processing lab results slow down clinical responses. Our biosensor seeks to address these issues with its at home monitoring as well as our associated easy-to-understand app. According to the doctor, a wearable biosensor that continuously measures creatinine at home would fill this critical care gap, allowing physicians to detect kidney function changes early, intervene before complications worsen, and ultimately reduce hospitalizations and costs.

Dr. Line Malha

We were able to create an interface between patients and doctors, allowing for our at-home monitoring system to track and trend creatinine levels. As per the advice of Weill Cornell Medicine nephrologist Dr. Line Malha, we were able to implement patient-friendly and informational features. The system also allows direct messaging to physicians and automatically updates the patient's medical chart with this data for clinical review. On the home page of our app, we show patients a color scale with the following indicators: green for average creatinine readings between 0.7 to 1.3 and red for <0.7 or orange for > 1.3. Users are only alerted if readings fall into the red or orange zones. This color-based system is used to minimize patient anxiety about testing results. However, for more thorough analysis, on a separate page doctors and patients will have access to a detailed history log of sensor readings graphs and average creatinine readings.

Key insights:

- High-risk AKI and transplant patients are motivated and open to using a home creatinine biosensor.
- Nephrologists confirm these patients are vulnerable to AKI and would benefit from continuous home monitoring to prevent costly hospitalizations.
- The biosensor app would track creatinine trends, alert users to significant changes, enable direct doctor messaging, and update medical records automatically.
- Simplicity, real-time alerts, and doctor communication are important features for users.
- This technology addresses delays in lab testing and has strong potential to improve outcomes and reduce healthcare costs.

4.2 Design of Validation Study

Based on our stakeholder interviews, we identified a key problem: elderly patients, especially those living in rural or winter-isolated regions, face serious barriers to regular kidney function monitoring. Many must travel long distances for routine tests, which often leads to delayed diagnosis of conditions such as chronic kidney disease (AKI). In response to this feedback, SensTech developed a conceptual solution combining several user-centered features:

- An online app with continuous monitoring capabilities
- Minimally invasive microneedles for painless sample collection
- A portable, take-home device designed specifically for elderly patients in snow heavy rural areas

The envisioned use case involves a patient applying the patch at home, where the device continuously collects and sends data to the app. Patients receive real-time updates and alerts, while clinicians can review long-term trends and intervene early if needed, reducing hospitalizations and improving peace of mind.

Because the sensor is not yet developed, we designed a first validation study using qualitative interviews to test the user-centered features. Participants consistently emphasized that having an easy, passive health tracker helped them feel more in control, stay consistent with their care, and better understand their health over time.

Mobile Phone App

As part of SensTech's validation testing for CreatConnect and its biosensor, we evaluated existing products in the market to assess user adoption potential. The Apple Watch served as a key proof of concept due to its similarity as a wearable device that measures health metrics and displays results via a mobile app. It rapidly dominated the market, becoming the world's best-selling watch by revenue within its first year and maintaining over 30% global market share for smartwatches since 2017. Its Health app, which includes continuous heart rate tracking during physical activity, demonstrates both

consumer demand and usability for real-time health monitoring. Customer interviews were conducted on 3 individuals that were all above 65 years of age that wore Apple Watches. All 3 of them said that they used the health app daily to look at their heart rate, and the app was simple and better than having the information displayed directly on the sensor itself. Based on its widespread adoption and functionality, our team used the Apple Watch Health app as a benchmark to validate the design and usability of CreatConnect's continuous monitoring app.

Building on this model, CreatConnect will integrate advanced performance and calibration features to ensure higher accuracy. The mobile app will assign a real-time signal quality score every few days based on parameters such as expected peak shape, background stability, and reference channel consistency. If this score falls below a defined threshold, the app will prompt users to refresh or replace the biosensor patch.

With AI on the rise in the medical field, we can integrate a training AI model that calibrates each user's physiological and environmental conditions by syncing with external health apps and wearable devices to account for activity levels, sleep patterns, and more. Environmental influences such as temperature, humidity, and motion tracked through weather apps and GPS will also be incorporated into calibration algorithms to account for variations in electrochemical behavior.

As CreatConnect will operate on a subscription model, we plan to include a baseline creatinine calibration sample in monthly shipments. This sample will release controlled amounts of creatinine for automated self-calibration via the app's self-test function. Users will also receive app-based reminders to clean or replace electrodes after extended use or if calibration detects deviations in sensitivity. Replacement electrodes or cleaning tools will be provided at regular intervals to prevent long-term biofouling, thereby ensuring sensor functionality and data accuracy over extended wear periods.

Microneedle-Based Sampling

Microneedling devices have gained significant traction as accessible, minimally invasive tools for skincare at home. Millions of consumers regularly use microneedling devices like the BeautyBio GloPRO or Dr. Pen M8, which create microchannels in the skin safely and with minimal discomfort. In the United States, the microneedling market surpassed $225 million in 2024 and is expected to attain around $489 million by 2034. Because this has become the norm, people are increasingly comfortable with using microneedling technology regularly in their personal care routines. This growing familiarity reduces barriers to adopting new microneedle-based applications, including clinical devices such as biosensors that sample interstitial fluid for health monitoring. We interviewed 5 individuals aged 30 to 65 who regularly incorporate at home microneedling devices into their skincare routines. Each participant reported using the devices at least once weekly to improve skin texture, diminish fine lines, and boost the absorption of skincare products. Ease of use and minimal discomfort were common themes among their experiences. Many expressed a preference for at-home treatments due to their convenience and affordability compared to professional sessions. Clear instructions and a sense of confidence in performing the procedure themselves were important factors that encouraged consistent use.

Take-Home Device

During the COVID-19 pandemic, at-home rapid antigen tests became widely used as a convenient alternative to lab-based PCR testing. These tests allowed individuals to selfadminister nasal swabs and receive results within minutes, eliminating the need to travel to clinics or wait for lab processing. By 2022, over 1 billion at-home COVID tests had been distributed in the United States alone. Their widespread adoption, particularly among older adults and high-risk individuals, helped normalize the idea of conducting health diagnostics from home. Surveys showed that the general population found at-home testing to be more convenient, accessible, and empowering than traditional

in-clinic diagnostics. To validate our take-home patch concept, we interviewed 10 individuals over the age of 65 who had used COVID-19 tests at home. All participants said they appreciated the ability to check their health status without visiting a doctor. The most common reasons for use were convenience, control over timing, and reduced exposure to others. Most mentioned that the simplicity of the instructions and ability to interpret results independently were key to their continued use.

Based on these interviews, we were able to determine that the three main added value features of our biosensor were not only useful but also have been proven to work in existing products. This gives us confidence that our design choices are headed in the right direction.

5. Team and support

5.1 Contributions of the team members

Business & Outreach:

Ian Chang: B&O team lead; Helped construct IP section.
Gemie Sonamai: Contributed to stakeholder outreach by contacting potential users and gathering insights for our validation planning
Virginia Liang: Helped construct IP section.
Vinesha Shaik: Helped construct IP section.

Wet Lab:

Alexander Harris: Wet Lab Lead; Led weekly meetings throughout the year, helped to finalize sensor design, and contributed to producing deliverables.
Eddie Hajjar: Helped to complete deliverables and finalize sensor design. He is next year's President.
Matthew Kiewski: Helped to complete deliverables and finalize sensor design. He is next year's Wet Lab Lead.
Garret Bouvier: Helped to complete deliverables and finalize sensor design. He is next year's Vice President.
Lauren Willson: Helped to complete deliverables and finalize sensor design.
Andrew Leibowitz: Helped to complete deliverables and finalize sensor design.

Dry Lab:

Alice Wei: Dry lab lead; Held meetings to work on dry lab components for the sensor.
Alima Deen: Helped to complete deliverables and finalize sensor design. She is next year's Dry Lab Software Lead.
Tyrone Chen: Helped to complete deliverables and finalize sensor design.
Tiffany Li: Helped to complete deliverables and finalize sensor design. She is next year's Dry Lab Hardware Lead.
Labib Aziz: Helped to complete deliverables and finalize sensor design.

5.2 People who have given support

Adelin Chan: Last year's co-lead, aided in transitioning the team to an official school project team and onboard this year's new team, educating new members on last year's research
Puloma Bishnu: Cornell University biomedical engineering alumni and last year's co-lead, aided in teaching new members R&D laboratory skills, recruiting new team members, and transitioning the new team

5.3 Sponsors and partners

Cornell University's College of Engineering Student Project Teams Organization has aided in providing the team with lab space, funding support, and team member recruitment processes. The team is currently in the process of acquiring sponsors, and does not currently have any other outside support.

6. Final remarks

The team would like to thank Professor Ibrahim and PhD student Nayan Banerjee for guiding R&D throughout this entire process, helping with testing and experimenting in the lab. The progress SensTech has made as a team to raise money, obtain lab spaces, and become officially recognized as a project team on campus has been incredible and is a testament to the cooperative efforts that the team and Cornell Project Teams have made to ensure the team's success. Lastly, the team would like to thank the SensUs committee for granting us the opportunity to compete. The SensTech team is incredibly excited to see where this next year will go!

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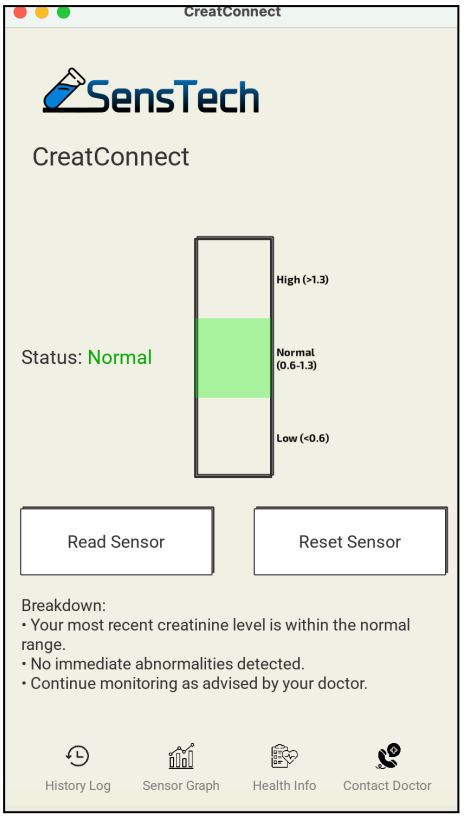
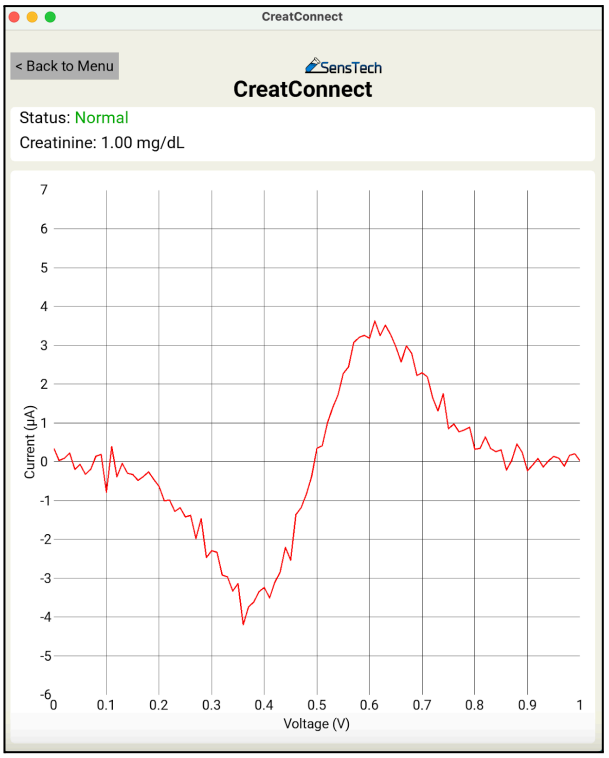
Appendix

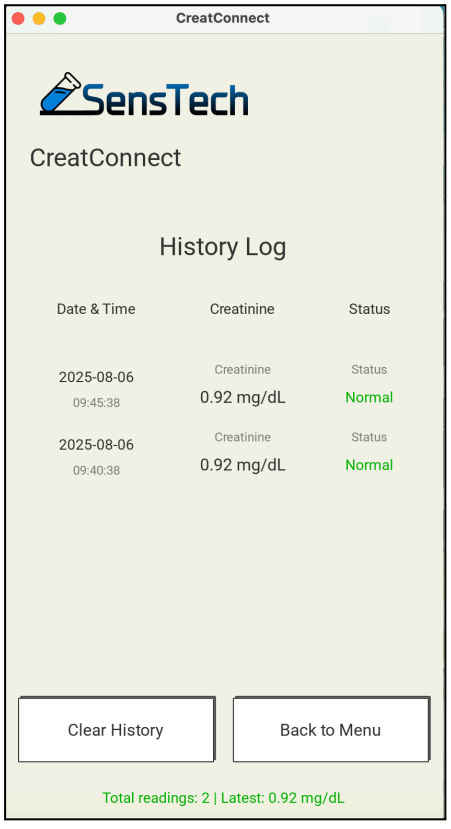
Appendix 1



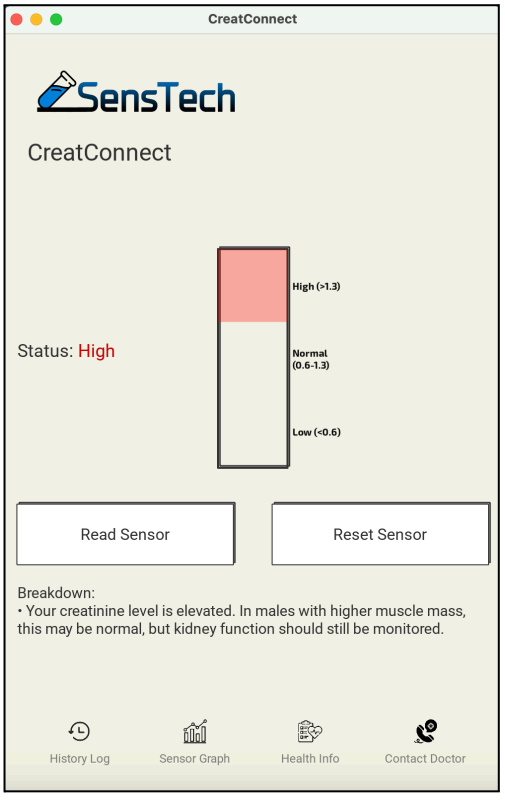
Appendix 2



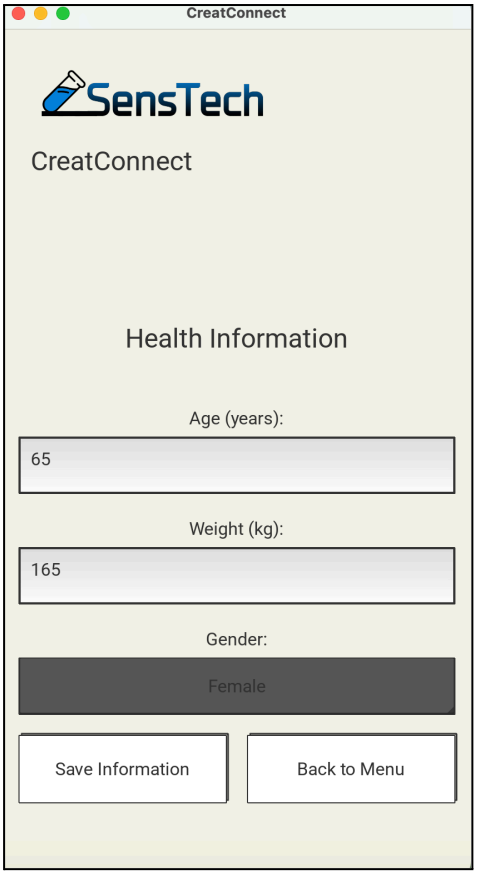
Appendix 3



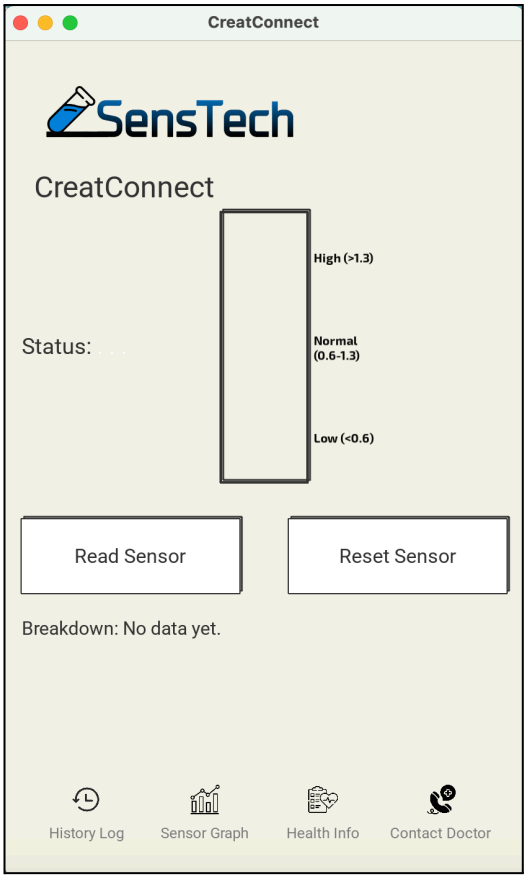
Appendix 4



Appendix 5



Appendix 6



Appendix 7

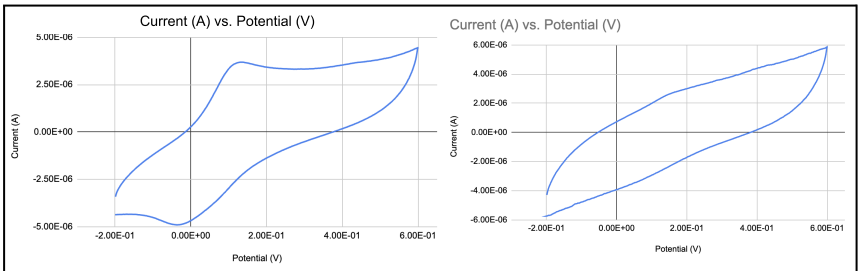


Figure 6: The graph on the left shows the resulting CV curve for a sample containing PBS + creatinine while the graph on the right shows one that is just PBS.