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A decade of greener care: Environmental, economic, and operational impact of the virtual stone clinic in the United Kingdom

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Introduction Outpatient care generates a significant environmental footprint through patient travel, energy use, and resource consumption. As the UK healthcare sector works toward Net Zero targets, sustainable redesign of routine services is essential. This study quantifies the environmental, economic, and operational benefits of the Virtual Stone Clinic (VSC), a telephone-based follow-up model for kidney stone disease (KSD).

Material and methods We conducted a prospective study of 854 patients managed in the VSC between March 2014 and December 2024. A total of 2,917 telephone consultations were delivered. Using postcode-based travel modelling and UK standard emission factors, we calculated reductions in travel distance, CO_2 emissions, fuel use, time burden, and cost compared with equivalent face-to-face (F2F) appointments. Clinic delivery costs were estimated using NHS Reference Costs.

Results The VSC avoided an estimated 27,138 km of patient travel, reducing CO_2 emissions by 4.04–4.42 tonnes. Patients saved over 560 hours of travel time and more than £2,000 in personal fuel costs. Clinic delivery costs were £201,273 lower than for equivalent F2F care, rising to over £204,000 when patient fuel savings were included.

Conclusions Over a decade, the VSC has delivered substantial environmental, economic, and time savings without compromising safety or access. This proven model offers a scalable approach to integrating environmental accountability into outpatient care, with clear potential for adoption across urology and other specialities in the UK and beyond.

Key Words: kidney calculi ‹› environment ‹› cost ‹› follow up ‹› virtual stone clinic ‹› telemedicine

INTRODUCTION

Healthcare faces a dual challenge: rising demand for services and the urgent need to reduce environmental impact. In the UK, healthcare accounts for an estimated 4% of national carbon emissions and nearly 40% of public sector emissions. The UK's Net Zero target requires eliminating direct emissions by 2040 and indirect emissions, including patient travel, by 2045 [1].

Although outpatient care is often viewed as routine and low impact, it in fact generates a significant environmental burden [2]. Face-to-face appointments typically require travel, sometimes long distances, for consultations that may last only minutes. For patients with stable chronic conditions, this model imposes unnecessary time, fuel costs, and logistical strain, all while contributing avoidable CO_2 emissions. When scaled across the millions of outpatient visits annually [3], the cumulative environmental and societal cost is significant. Virtual models of care, especially those using telephone or video follow-ups, provide an increasingly viable alternative that can reduce emissions and ease the everyday burden on patients and their families [4].

Kidney stone disease (KSD) is a common, recurrent condition that lends itself well to this model of care [5]. Many patients remain asymptomatic for long periods, yet require ongoing surveillance to monitor stone progression, metabolic risk factors, or previous interventions. Traditional in-person follow-up is not always necessary for safe management, especially when imaging and blood test results can be reviewed remotely [6]. For working adults, parents, those with mobility issues, or patients living in rural areas, removing the need to travel for such appointments can translate into real, tangible benefits: less time off work, fewer childcare disruptions, lower transport costs, and improved access to care without putting clinical safety at risk.

In our university academic hospital, urology department has established the Virtual Stone Clinic (VSC) as a telephone-based, nurse-led service designed to manage patients with kidney stones who are suitable for remote follow-up after first-hand assessment by specialist urologists. The model is supported by urology consultants, with patients escalated to in-person care only when clinically indicated or requested by the patients. The VSC stood the test of time and demonstrated that it is a safe and efficient model, freeing up valuable clinic capacity while maintaining high standards of patient care [7].

However, the environmental impact of this shift in service delivery has not been fully studied. As healthcare increasingly adopts digital and remote methods, it is essential to quantify not only clinical and financial outcomes but also the broader sustainability gains [8]. Capturing the carbon savings, travel reductions, and fuel cost benefits of models like the VSC allows for a more complete understanding of their value, not just to the individual patient, but to the healthcare system and the planet.

In this study, we evaluate the environmental impact of the VSC across a 10-year period. Using real-world data from over 850 patients and nearly 3,000 virtual appointments, we quantify reductions in CO_2 emissions, avoided travel mileage, time savings, and economic benefit. These findings provide compelling evidence for the integration of environmentally sustainable care pathways into long-term outpatient service planning in all specialities.

MATERIAL AND METHODS

This was a prospective study was carried out at an academic tertiary urology centre in the United Kingdom. The VSC was established in March 2014 as a nurse-led, consultant-supported service for the follow-up of patients with kidney stone disease. All consultations were conducted by telephone, with investigations such as imaging and blood tests arranged locally. Patients were reviewed remotely and remained under VSC follow-up if stable, with escalation to face-to-face (F2F) clinic or intervention arranged only if clinically indicated.

Data collection: Clinic records provided the number of telephone appointments per patient and patient postcodes. Round-trip distances to the hospital were calculated using postcode data. A total of 854 patients were included. For each patient, the number of VSC telephone appointments attended was recorded. The distance was used to calculate the total round-trip travel that would have occurred if appointments had been conducted in person.

Environmental analysis: Calculations were based on standard UK emission factors for passenger vehicles [9], with separate estimates for petrol and diesel users. Fuel usage and cost savings were also calculated using NHS travel cost guidance, with petrol assumed at 0.751 litres per visit (approximately £1.00) and diesel at 0.57 litres per visit (approximately £0.80), using average fuel prices from June 2025 [10].

Cost analysis: We compared the financial cost of delivering outpatient care through the VSC with the traditional face-to-face model. NHS Reference Costs were used to estimate appointment costs, with F2F consultant-led clinics priced at £163 per appointment and VSC telephone reviews at £94, based on the 2023/24 National Cost Schedule [11]. Total clinic cost savings were calculated based on 2,917 VSC appointments delivered across the 10-year period.

Time analysis: Average round-trip travel distances were converted into estimated travel times using standard local speeds.

All data were anonymised prior to analysis, and calculations were performed using Microsoft Excel.

Bioethical standards

Since the work concerns the provision of services, the consent of the bioethics committee was not required.

RESULTS

Over the 10-year period, between March 2014 and December 2024, 854 patients completed 2,917 telephone consultations, averaging 3.41 per patient. Using postcode data, the round-trip distance each patient would have travelled to attend the hospital in person was calculated. These distances were used to estimate the environmental and logistical savings achieved by replacing in-person follow-up with telephone-based care (Table 1).

The average round-trip distance for one clinic appointment was 9.3 kilometres. When multiplied across the average number of appointments per patient (3.41), the estimated total travel distance saved per patient was 31.7 kilometres. For the entire cohort, this amounted to 27,138 kilometres of avoided travel over the 10-year period.

To assess the environmental impact, standard UK government emission factors were applied. For petrol vehicles, the avoided travel translated to a total CO_2 saving of 4.04 tonnes. For diesel vehicles, the CO_2 saving was slightly higher at 4.42 tonnes. These calculations were based on standard vehicle emission rates (in kg CO_2/mile), converted to kilometres and adjusted for round-trip travel. Although individual reductions may seem minor, the cumulative savings highlight how simple outpatient redesigns can contribute meaningfully to reducing the carbon footprint of routine care.

Fuel consumption and cost savings were calculated using NHS travel cost guidance and verified against national average fuel prices as of June 2025. On average, each petrol vehicle used 0.751 litres of fuel per round trip (estimated at £1.00), while diesel vehicles used 0.57 litres (approximately £0.80). By applying these consumption rates to the number of appointments avoided, we estimated total fuel savings of £2,885 to £2,917 for petrol users and £2,331 to £2,335 for diesel users.

Time savings were estimated using average speed to convert travel distance into approximate time per journey. Based on an average travel distance of 9.3 kilometres per appointment, we calculated that each patient saved approximately 39.4 minutes in total travel time across their VSC follow-up. Aggregated across all patients, this saving equated to 33,647.6 minutes, or approximately 561 hours of travel time avoided. While this estimate does not account for waiting time in hospital clinics, it nonetheless reflects a substantial reduction in time burden, particularly for patients with mobility challenges, those living at a distance, or those balancing work and family responsibilities.

The financial impact on the healthcare system was also significant. According to NHS Reference Costs, a consultant-led face-to-face urology clinic appointment is estimated at £163. In contrast, the cost of a nurse-led virtual telephone consultation is £94. Based on the 2,917 VSC appointments delivered, the total cost using the virtual model was £274,198 compared to a projected £475,471 for face-to-face care. This yielded a direct clinic cost savings of £201,273 for the facility. When fuel savings are factored in, the total savings amounted to £204,159 (petrol scenario) and £203,605 (diesel scenario) (Table 2).

These results demonstrate the wide-ranging impact of the VSC model. What began as a service innovation to manage stable stone patients more efficiently has, over a decade, delivered substantial reductions in unnecessary travel, reduced healthcare-related carbon emissions, reclaimed patient and healthcare workers time, and generated six-figure savings for the UK National Health Service (NHS). This is not only a sustainable care model, it is a practical,

Table 1. *Summary of Virtual Stone Clinic (VSC) activity and patient travel savings*

Metric	Value
Patients managed (March 2014 – Dec 2024)	854
Telephone consultations generated	2,917
Average virtual appointments per patient	3.41
Average round-trip distance per appointment	9.3 km
Estimated total travel distance saved per patient	31.7 km
Total avoided travel for entire cohort (10 years)	27,138 km

Table 2. *Environmental, time, and financial impact of VSC*

Metric	Value
CO_2 saving (petrol vehicles)	4.04 tonnes
CO_2 saving (diesel vehicles)	4.42 tonnes
Fuel consumption per round trip (petrol)	0.751 litres (£1.00)
Total fuel savings (petrol)	£2,885 – £2,917
Fuel consumption per round trip (diesel)	0.57 litres (£0.80)
Total fuel savings (diesel)	£2,331 – £2,335
Time saved per patient (total travel time)	39.4 minutes
Total time saved for all patients	33,647.6 minutes (approx. 561 hours)
Cost of a consultant-led F2F urology clinic appointment	£163
Cost of nurse-led virtual telephone consultation	£94
Total cost (virtual model)	£274,198
Projected cost (face-to-face care)	£475,471
Direct clinic cost savings	£201,273
Total savings (petrol scenario, incl. fuel)	£204,159
Total savings (diesel scenario, incl. fuel)	£203,605

measurable contribution toward greener, more efficient outpatient care.

DISCUSSION

Environmental impact of virtual follow-up

This 10-year prospective study demonstrates real-world evidence that virtual outpatient care is not only clinically safe and cost-effective [7], but also environmentally impactful. Through 2,917 telephone consultations delivered by the VSC, over 27,000 kilometres of patient travel were avoided, leading to an estimated reduction of 4.04–4.42 tonnes of CO_2 emissions and greenhouse gases [12]. These savings are equivalent to planting over 180 mature trees, removing multiple vehicles from the road for a year, or powering a UK household for six months. While these numbers may appear modest on their own, they represent substantial gains when considered over time and at scale [13].

These avoided emissions represent approximately 0.2–0.3% of the average annual outpatient carbon footprint of an NHS hospital. While this may seem small, but it is worth remembering that this contribution came from a single service, managing a single condition [14]. This contribution aligns directly with the NHS's plan to become the world's first net-zero national health system. According to the NHS Net Zero strategy, the organisation aims to eliminate direct emissions by 2040 and reach net zero for indirect sources, including patient travel, by 2045 [1]. Patient travel alone accounts for nearly 10% of the NHS's total carbon footprint [15]. By reducing thousands of routine journeys, the VSC model shows how even simple operational changes can directly contribute to these national sustainability goals.

Why reducing CO_2 matters – for people, systems, and the planet

CO_2 emissions are more than just a number that reflects an environmental metric; they are directly linked to worsening public health, climate instability, and increasing demands on healthcare systems [16]. High atmospheric CO_2 levels are a key driver of global warming, which intensifies heatwaves, wildfires, flooding, and air pollution [17, 18]. These consequences disproportionately affect vulnerable populations and increase the incidence of respiratory and cardiovascular illness, heat-related mortality, and mental health strain [18].

In contrast, reducing CO_2 emissions contributes to cleaner air, healthier environments, and lower long-term disease burden. Every tonne of CO_2 avoided is a step toward delaying catastrophic climate tipping points and improving planetary health. Healthcare systems have a unique chance to lead in the climate crisis as both part of the problem and solution [12].

Time and travel benefits

Beyond environmental metrics, the VSC significantly reduced the burden on patients and healthcare workers. The cohort reclaimed over 560 hours of travel time, with an average savings of 39.4 minutes per patient [13, 19]. This reduction is meaningful, particularly for those living in remote areas, individuals with mobility challenges, and working adults who would otherwise need to arrange transport, take time off work, or rely on family and carers for support [15].

Other findings in the literature align with these practical benefits. Wong et al. reported high levels of patient satisfaction and significant time, cost, and environmental savings associated with telehealth implementation in a single-centre urology service, supporting the case for sustainable care models that centred both the planet and the patient [20].

Fuel use and financial efficiency

Over the course of the study, the VSC model reduced fuel consumption by over 2,000 litres, saving patients hundreds of litres of fuel and over £2,000 in personal travel expenses depending on vehicle type [9, 10]. System-wide financial savings were also substantial. The cost of delivering 2,917 face-to-face appointments was estimated at £475,471, compared to just £274,198 for virtual care, a saving of £201,273. Including patient fuel savings, the total benefit exceeded £204,000 [11, 13].

Such savings could be reinvested back in core services. For instance, £204,000 could fund two new cystoscopy towers, more than 35 portable ultrasound machines, or multiple nurse-led one-stop clinics. This reinvestment has the potential to improve waiting times, enhance diagnostic capabilities, and encourage innovation in frontline care [19, 21].

Clinical capacity

An overlooked but critical benefit of the VSC model was its impact on clinical workforce efficiency. By safely managing stable patients remotely [7], consultants and registrars were able to dedicate more time to acutely unwell or complex patients. This redistribution of effort not only improved the use of specialist expertise but also enhanced the overall responsiveness of the service [3]. In an era of increasing demand and not enough staffing, this shift in care delivery supports both patient outcomes and staff well-being [22].

Scalability and missed opportunity

One of the most compelling questions raised by this study is, if this model works so well, why isn't it used more widely?

The technology required for telephone consultations is universally available. The benefits, which include reduced emissions, cost savings, and greater patient flexibility, are consistent; numerous studies have shown that both patients and healthcare workers prefer virtual consultations over face-to-face clinics, including a study by Aydogdu et al. [23] that found high satisfaction rates for both urological patients and their surgeons with virtual care.

And yet, many services continue to default to inperson follow-ups, even for clinically stable patients. This tendency reflects a broader inertia in healthcare system design, where sustainability is often ignored or overlooked entirely in service planning [21].

The VSC model demonstrates that we should treat environmental impact as a measurable outcome of care. If applied to 10,000 patients annually, the model could prevent more than 90,000 km of travel, save 15+ tonnes of CO_2 emissions, and avoid £700,000–£800,000 in direct and indirect costs [13]. The only barrier to adoption is organisational will.

Broader applications across urology and medicine

Kidney stone disease is only one of many conditions suitable for remote follow-up. Similar virtual care pathways could be implemented for patients undergoing prostate cancer surveillance, benign renal cyst monitoring, post-operative reviews, stable bladder conditions, or long-term catheter care [8]. Beyond urology, services such as endocrinology, general surgery, respiratory medicine, and dermatology are already testing or implementing virtual models [21].

At our own centre, the Virtual Pulmonary Clinic has seen similar success. Puthumana et al. [24] demonstrated that telemedicine in respiratory follow-up reduced appointment burdens, preserved clinical outcomes, and improved resource utilisation. Our findings mirror the results of this study and reinforce the case for embedding virtual care in a broader outpatient plan.

Carbon accountability in outpatient care

Healthcare has a legal and moral obligation to decarbonise. Virtual care is a proven, scalable intervention that delivers carbon savings alongside improved efficiency and patient experience. When carbon savings are taken into account in business cases, QI projects, and commissioning decisions, sustainable care becomes visible, valued, and easy to grow [22].

We must begin to measure carbon as a routine outcome in service planning. Without it, the climate impact of care will remain invisible, undervalued, and under-addressed. Virtual care is not merely a service innovation, it is a climate intervention [25]. The tools exist and what is needed now is the commitment to use them.

CONCLUSIONS

The VSC shows that environmentally sustainable care can be delivered safely, efficiently, and at scale using infrastructure already in place. Over ten years, this modest change in follow-up practice has yielded measurable reductions in greenhouse gas emissions, fuel consumption, patient travel time, and healthcare costs. These gains go beyond metrics, and they challenge how we define value in healthcare.

In the context of climate change, rising service demand, and constrained clinical capacity, models like the VSC offer a proven route to greener, smarter care. The tools are already available and what remains is the resolve to use them.

CONFLICT OF INTERESTS

The authors declare no conflict of interest.

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ETHICS APPROVAL STATEMENT

The ethical approval was not required as this is a review of service provision.

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