Optimizing Nurse and Dialysis Unit Scheduling for Hemodialysis Patients

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Abstract

As the prevalence of kidney disease continues to rise, the increasing demand for dialysis services must be addressed to ensure efficient and patient-centric care. Currently, hemodialysis poses significant challenges for patients, and it is clear that there is a need to improve the scheduling process to enhance their overall experience. This paper proposes an optimization strategy that can be implemented to improve nurse and dialysis unit scheduling for the benefit of patients. A case study from a unit on an island in Tunisia (North Africa) is considered to illustrate that optimizing nurse and dialysis unit scheduling can better accommodate the growing number of patients requiring hemodialysis and provide timely and accessible care. This includes strategically managing resources, ensuring appropriate staffing levels, and implementing efficient scheduling systems that prioritize patient needs. This paper recognizes the importance of optimizing appointment scheduling for patients in the dialysis unit, while also considering the constraints on nurses and equipment availability. By minimizing patient wait times, implementing a safety net measure, and exploring innovative solutions, it is shown that the quality, reliability, and efficiency of care provided in the hemodialysis setting is improved. This research contributes to the broader goal of improving patient experiences, addressing healthcare provider challenges, and optimizing resource utilization in dialysis units.

Keywords
Dialysis scheduling, patient care, resource management, optimization.

1. Introduction
The kidneys play a vital role in eliminating waste products, maintaining fluid balance, and regulating electrolytes in the human body. They receive about 25% of the heart's total blood output and filter approximately 187 liters of liquid daily. Only 1% of the initial filtrate ends up as waste products in the urine, while the remaining 99% is reabsorbed into the bloodstream to prevent dehydration (Sherwood 1993). Blood initially flows into the kidney through the renal artery, which eventually branches off into various blood vessels until it reaches the nephron, the functional unit of the kidney (Figure 1). The nephron contains the glomerulus, which oversees the filtration of the blood, as well as the tubule, which is the site of secretion and reabsorption of important amino acids, vitamins, and solutes. Waste products like urea and creatinine, derived from food and tissue breakdown, are concentrated in urine, whereas, active and passive transport mechanisms will reabsorb the necessary nutrients back into the blood. The kidneys also ensure the stability of extracellular fluid volume and electrolyte levels by adjusting water and electrolyte excretion based on intake. Additionally, the kidneys serve as an endocrine organ, producing hormones like erythropoietin for red blood cell production and activating vitamin D for proper bone health. Moreover, they act as the primary route for eliminating foreign substances, including drugs, food additives, pesticides, and other components from the body. Kidney failure results in the accumulation of waste products, disruption of fluid and water balance, and dysfunction of the kidney's endocrine functions. This leads to impairment in multiple organ systems, resulting in a toxic state called uremia, which, if left untreated, can be fatal. Kidney failure is a chronic condition that requires intensive and

expensive dialysis treatments, and in some cases, transplantation. The number of such patients has consistently risen over the years (USRDS 2002; Coresh et al. 2007; Hosseinpanah et al. 2009; and Ulasi et al. 2013). Dialysis can serve as a substitute for the excretory function of the kidneys. Two primary forms of dialysis exist: hemodialysis and peritoneal dialysis. Hemodialysis purifies the blood by using an external dialysis machine, while peritoneal dialysis involves introducing sterile fluid into the peritoneal cavity, utilizing the peritoneal membrane as a natural filter. Peritoneal dialysis can be performed at home by the patient, whereas hemodialysis is typically administered by healthcare professionals in a dialysis center. This paper focuses on the scheduling and performance improvement of hemodialysis centers.

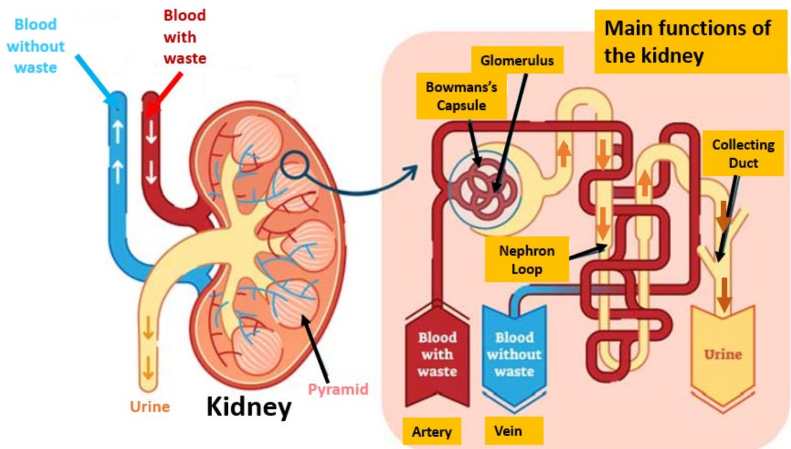

Figure 1. The main functions of the Kidney and the Nephron loop (Biodictionary.net, 2019).

Hemodialysis is a procedure that involves removing blood from the body and circulating it through a system of small, porous tubes submerged in a solution called dialysate (Figure 2). Hemodialysis is a challenging process that many individuals with kidney disease must endure (Wang et al. 2023). Extensive research has been conducted in this area to optimize the entirety of the process (Coresh et al. 2007; Kandakoglu et al. 2020; Ovwasa et al. 2023; Wang et al., 2023). Many patients suffer from kidney disease, and as the incidence rate continues to rise, the need for nurses and dialysis units increases. Practitioners believe that addressing these challenges can be accomplished through various measures, namely the expansion of the capacity of dialysis units by incorporating additional dialysis stations, constructing new dialysis centers, or extending the operating hours of existing facilities. An effective approach that is more economical and will enable the management of resources more efficiently and minimize treatment delays is to optimize the scheduling of nurses and dialysis units for patients. Many solutions have been explored, with many focusing on the optimization of the process that takes place at clinics. According to previous research, minimizing patient wait times and maximizing the number of patients scheduled are the most important objectives (Fleming et al. 2020).

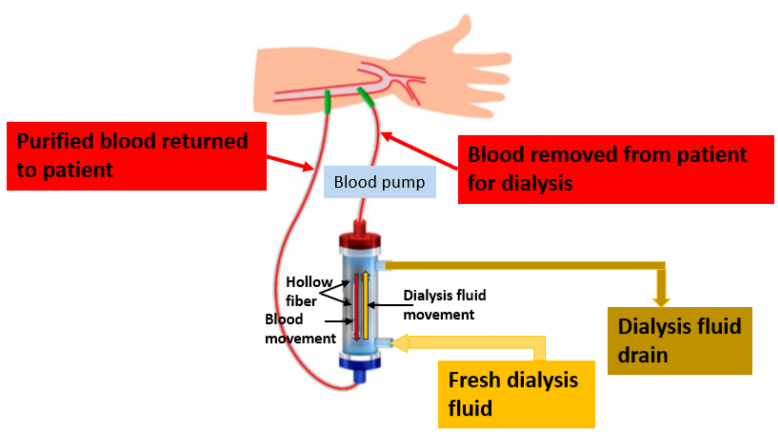

Figure 2. Blood filtration process during Hemodialysis (Chen et al. 2022).

1.1 Objectives

This paper aims to tackle the appointment scheduling problem for an increased number of patients in a dialysis unit while also considering the constraints imposed by nurses' availability and equipment limitations. The primary objective is to create an optimal schedule accommodating every patient, while minimizing wait times and increasing the overall efficiency of a dialysis unit in Hôpital Régional Salim El-Hadhri De Kerkennah, Tunisia. By addressing these challenges, we can alleviate the burden on healthcare providers and improve the quality of care provided to patients. It is crucial to explore innovative solutions and best practices in optimizing scheduling within the dialysis unit. This may involve the development of scheduling algorithms or software systems that consider various factors, including patient needs, nurse availability, and equipment utilization. By utilizing technology and data-driven approaches, we can create a more streamlined and patient-centric scheduling process. One important aspect of the work presented here is the implementation of a safety net measure. This involves keeping a certain percentage of dialysis units idle to accommodate emergencies or instances when there are breakdowns in the already assigned units. This proactive approach ensures that unforeseen circumstances can be managed effectively without compromising patient care or causing unnecessary delays. By optimizing the scheduling process in the hemodialysis unit in this fashion, it is illustrated through a case study that the reliability and quality of care provided to patients is enhanced. Moreover, it helps maintain a consistent and efficient workflow, reducing patient discomfort, and promoting better health outcomes.

2. Literature Review

Many patient scheduling studies have appeared over the years to schedule hospital units and assign caregivers to units and nurses, while also considering the assignment restrictions of patients and their activities (Ozkarahan 1989; Warner, 1976; Howell 1966; Maier-Rothe and Wolfe 1973; Ozkarahan 1991; Caron et al. 1999; and Okada and Okada 1988). The objective of these scheduling studies is to efficiently allocate patients to limited hospital resources, considering factors such as patients' waiting time, satisfaction, and clinic completion time. Such scheduling tasks are time-consuming to be performed manually because of the many intricacies that must be incorporated, including staffing and allocation decisions. Azaiez and Al Sharif (2005) proposed a 0-1 linear programming model to improve current manual-made schedules of assigning nurses to shifts and workdays to secure appropriate service care. Their model considered several constraints, such as the need for a certain number of nurses on each shift, the availability of nurses, and the preference of nurses for certain shifts or days off. Ahmadi-Javid et al. (2017) presented a review of recent contemporary outpatient scheduling problems, providing valuable decision-support tools for designing and planning outpatient appointment systems.

In the context of hemodialysis units, several researchers proposed optimization models to schedule patients to units and improve efficiency while taking special consideration of supplies, staffing, and workflow. For instance, Peña et al. (2013) presented an optimization model that minimizes the lateness of patients' treatments and the total idle time of the dialysis machines while considering constraints on staff availability and the dialysis protocols prescribed by a treating nephrologist. In the problem, patients were assumed to have varying treatment time requirements, and the dialysis devices were grouped into blocks based on the patient's specific needs. The model also considered the capacity of the dialysis unit and the number of machines and nurses available. The model was tested on data from a hospital in Ecuador. The investigation revealed that the implementation of optimized schedules led to significant improvements. Patients experienced an impressive 81% decrease in average waiting time for their treatments, while the total idle time of dialysis machines saw a remarkable reduction of 40%. Additionally, it was discovered that the optimized schedules resulted in a 67% decrease in the number of treatments that had to be canceled due to delays, and a 25% reduction in staff overtime hours worked.

Liu et al. (2019) considered a heuristic approach for scheduling hemodialysis services in patient care. They proposed a synthetic-objective optimization model that incorporates multiple criteria, including minimizing device utilization, reducing the time of treatment, and accommodating patient preferences. They considered both a basic heuristic approach and a rollout algorithm based on the heuristic approach, which constructs three levels of treatment schedules sequentially. Real case studies were conducted to compare the performance of the rollout algorithm and the basic heuristics. The computational results demonstrate that the rollout algorithm significantly enhances patient satisfaction while simultaneously reducing the need for night shifts.

Fleming et al. (2020) recognized that dialysis patients have complex medical needs that require careful management and coordination of care. The authors presented a mathematical programming model aimed at scheduling shifts for dialysis providers to reduce patient waiting times at the start of the dialysis after the patient's arrival, and considered lateness after the scheduled finish time, which is particularly important for transportation services. The model was incorporated into a decision support tool using Microsoft Excel to analyze the delivery of dialysis services and identify potential areas for enhancement. A case study was conducted at a dialysis clinic to showcase the effectiveness of this tool. The results demonstrated noteworthy enhancements in patient satisfaction, reduced wait times, and improved clinical outcomes resulting from their approach.

Kandakoglu et al. (2020) proposed a Home Dialysis Scheduler System (HDSS) that utilizes a mixed-integer linear programming model to generate nurse itineraries daily. The objective of the system was to minimize the cost associated with providing home dialysis for a specific group of patients. The model considered various constraints, including nurses' overtime work, accommodating mealtime breaks (such as lunch or dinner, depending on shift times), and adhering to restrictions and preferences related to visit times. Additionally, the model encompassed achieving a balanced workload for nurses, and accounted for various types of services provided to patients. The model has the flexibility to dynamically adapt the schedule in real-time to accommodate changes in nurse availability or unforeseen circumstances, such as patient cancellations. The proposed model was developed using real-world data from a home dialysis unit in Canada, and the results showed that the model was able to optimize the scheduling and routing of nurses, reducing travel time and improving patient satisfaction.

A very recent study by Reihaneh et al. (2023) considered patient appointment scheduling at hemodialysis centers. They considered the fact that patients must be scheduled for several appointments each week at the center. They proposed a set-partitioning model that allows for partial schedules. Due to the size and complexities of the problem they solved, they had to employ numerous improvement strategies to enhance the computational tractability of their model. These enhancements include decomposition, column, generation, and the employment of heuristics. They compared the optimal schedules obtained by their algorithm to the schedules currently used, and the improvement to leftover appointments reached 98%; the hours of deviations per patient improved by 46%.

3. Methods

The goal of this paper is to schedule patients for dialysis treatment during the busy summer months as well as to minimize patient wait times in a dialysis clinic at Hopital Régional de Kerkennah in Tunisia. In this clinic, there are three dialysis bays or suites, where the largest bay has nine dialysis machines which are always operational; one of the smaller bays has two dialysis machines, and the final bay has one. All the dialysis machines cannot be operated simultaneously, as there are only three nurses per 4-hour dialysis session. Each nurse can take responsibility for three patients in the dialysis unit.

The clinic is operational six days a week, and the working hours are from 7:00 am to 7:00 pm. Throughout the year, 27 patients require treatment; however, during the summer, 36 patients require treatment. Using mathematical programming techniques, we will determine the optimal solution to schedule the increased number of patients that require treatment. Each dialysis run takes approximately four hours, with each run beginning with a 15-minute preparation time (Figure 3). During this preparation time, a patient is connected to the machine using two needles: one for extracting blood and the other for returning filtered blood back into the body. During the procedure, blood exits the patient's body through a tube and flows through the dialyzer or artificial kidney to eliminate waste products and excess fluid. The dialyzer filters and purifies small amounts of blood at a time using a cleansing solution known as dialysate. Subsequently, the treated blood returns to the patient's body through another tube. The duration of the procedure is three hours. In general, patients require 9 to 12 hours of dialysis per week and are scheduled to visit the clinic three times per week. Finally, a 30-minute time slot is needed for cleaning and disinfecting the hemodialysis stations, as illustrated in Figure 3. The in-depth cleaning procedures are outlined in Figure 4. After the run is finished, the next shift of nurses would come to replace them, and the process is repeated, including the preparation time. There are seven nurses on payroll, but only six would be working during the day.

The approach that was taken to solve the problem encompasses several steps. First, the scope of the problem with respect to time (weekly, yearly, etc.) and complexity is discussed. Next, the data necessary to solve the problem gathered from Hopital Régional de Kerkennah and other references is described. Next, the decision variables and constraints are created to accurately represent the working conditions and demand at the clinic. After defining suitable decision variables, they are used to create the objective function for the model. In the context of the dialysis clinic, the objective function represents the waiting time for a patient and will be minimized in the model.

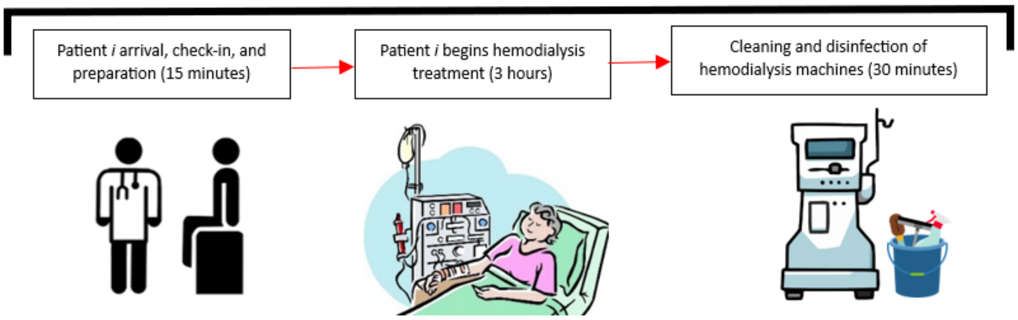

Figure 3. Hemodialysis treatment process.

Before Beginning Routine Disinfection of the Dialysis Station

- Disconnect used blood tubing and dialyzer from the machine.
- Discard tubing and dialyzers in a leak-proof container.
- No visible soil or blood on surfaces.
- Discard all single-use supplies.
- Move reusable supplies for cleaning and disinfection before storage or return to a dialysis station.
- Remove gloves and perform hand hygiene.

Routine Disinfection of the Dialysis Station – AFTER patient has left station

- Wear clean gloves.
- Apply disinfectant to all surfaces in the dialysis station using a wiping motion (with friction).
- Ensure surfaces are visibly wet with disinfectant.
- Allow surfaces to air-dry.
- Disinfect all surfaces of the emptied priming bucket.
- Allow bucket to air-dry before reconnection or reuse.
- Keep used or potentially contaminated items away from the disinfected surfaces.
- Remove gloves and perform hand hygiene.

Figure 4. Dialysis station routine disinfection guidelines (CDC 2023).

The most significant challenge that was faced when solving the problem was the incorporation of the different circumstances that affect the usual operations of the clinic. There is an element of seasonality at the clinic as the demand for dialysis increases during the summer months. The clinic is normally open six days a week, but in the case of an emergency, it can open on a Sunday. Maintenance is done twice a year, so that would mean that an entire dialysis session would be missed for that shift, and the clinic would have to open on a Sunday in order to process the patients. The clinic staff can also make use of the other dialysis machines in the other bays in these circumstances. In some instances, a patient may still be bleeding after treatment; must stay seated until the bleeding stops, which can take anywhere from five minutes to three hours. In these circumstances, the dialysis machines in the other bays could be used to overcome this complication.

The number of dialysis machines is limited, and therefore, we must optimize the patient waiting time and minimize the use of resources by employing 9 dialysis machines and keeping three on standby. The maintenance days will be set for the first week of March, and the first week of September. The number of dialysis machines being used is set to nine to account for emergencies, unexpected breakdowns, and the availability of nurses.

There are several constraints that dictate the operation of the clinic. Constraint (1) below ensures that every patient is assigned at most to one dialysis unit for any given day.

$$\sum_j X_{ijt} \leq 1, \forall i, t \qquad (1)$$

The variable X_{ijt} is a binary variable that assumes a value of 1 if patient *i* is assigned to dialysis unit *j* on day *t*. The sum is over all dialysis units *j* to require that at a given day a patient is assigned to at most one unit.

In order to ensure that each patient is allocated the required frequency of dialysis of three times per week, the following constraint is written:

$$\sum_j \sum_t X_{ijt} = 3, \forall i \quad (2)$$

The above set of constraints are written for each patient because each patient must visit 3 times per week. There are 36 patients during the months of May-Aug, and 27 patients every other time of the year.

The following constraint limits the clinic to 18 patients per day to take into account the availability of personnel, cleaning operations, and setting up of the units:

$$\sum_j \sum_i X_{ij} \quad \leq \quad 18, \quad \forall t \quad (3)$$

A typical schedule would begin at 7:00 AM with each nurse preparing 3 machines, each taking 15 minutes. Each machine will be used twice per day, giving patients enough time to come whenever they like, as long as it is before 8:00 AM for the morning session and between 12:00 PM and 3:00 PM for the afternoon session. The machines will be cleaned twice, and patients will be given time to bleed for 30 minutes. This is taken into account by allowing the machines to be used at most twice per day:

$$\sum_i X_{ijt} \leq 2, \forall j, t \quad (4)$$

Each dialysis session takes 240 minutes (four hours) and the objective function is to minimize the overall operation time of the unit while scheduling all patients 3 times a week as per the above constraints. The 240 minutes include setting up patients to units and cleaning operations. The objective function is written as:

$$\text{Minimize } 240 * \sum_i \sum_j \sum_t X_{ijt} \quad (5)$$

4. Results and Discussion

The optimization problem described in the previous section consists of minimizing an objective function (equation 5) subject to a set of constraints (1- 4) that dictate the appropriate operation of the dialysis unit. The unknowns in the problem are the assignment variables X_{ijt} that will indicate which patient is assigned to which unit and on what day. These variables are all binary variables, and the problem is a pure binary optimization problem.

The problem was solved using the optimization software GAMS (GAMS, 2021). The GAMS software is a valuable tool for addressing planning and scheduling problems. It is specifically designed for constructing and solving optimization models, offering convenience, speed, and efficiency in tackling planning challenges. It employs a user-friendly modeling language that simplifies the process of programming optimization problems. The language structure is straightforward and intuitive, enabling users to describe complex mathematical models with fewer command statements. Additionally, GAMS provides seamless integration with other data files, allowing for easy model solving, data input and output, and analysis of related problems; in case the current model is applied to much larger dialysis units with many more patients.

The busy case during summer consisting of 36 patients was solved first. As mentioned before, only 9 dialysis units are employed, and the other three were left on standby for emergency situations and to account for any random machine breakdown. This is a simplified version of considering the stochasticity of the current dialysis scheduling problem, and it is planned to prepare a stochastic programming model as a follow-up work to take care of such complexities.

Table 1 shows the assignments of patients 1 – 36 to the different units and throughout the days of the week. The letters M to S indicate the six days (*j* = 1 to 6) of the week, keeping Sunday a day off. The dialysis units are labeled Machines A – I, and the patients are numbered from 1 to 36. The problem has 1944 binary variables, 313 constraints, and 9721 nonzero elements. There are no nonlinearities in the current model. An optimal solution of 25920 min was obtained after 15 iterations. The solver used within GAMS was CPLEX, and the computer resource usage (CPU) was 0.063 seconds. As can be seen, all constraints of assigning three-time slots per week to each patient are satisfied. Each machine is also assigned to only two patients per day. All patients are taken care of by the schedule depicted in Table 1. There is enough time left for the nurses and operators to perform the cleaning operations, set up the patients to units, perform any necessary maintenance, and take a break between patients.

Table 1. Optimal schedule of the dialysis unit during the busy summer days.

	M	T	W	Th	F	S
Machine A	1,2	1,2	1,2	3,4	3,4	3,4
Machine B	5,6	5,6	5,6	7,8	7,8	7,8
Machine C	9,10	9,10	9,10	11,12	11,12	11,12
Machine D	13,14	13,14	13,14	15,16	15,16	15,16
Machine E	17, 18	17, 18	17, 18	19,20	19,20	19,20
Machine F	21,22	21,22	21,22	23,24	23,24	23,24
Machine G	25,26	25,26	25,26	27,28	27,28	27,28
Machine H	29,30	29,30	29,30	31,32	31,32	31,32
Machine I	33,34	33,34	33,34	35,36	35,36	35,36

After solving the scheduling for the summer months, other circumstances were considered to account for any complications that may arise. In Table 2, a run is made for the scenario where patients 9 and 17 are not available on Mondays, patients 18 and 30 are not available on Tuesdays, and patients 5 and 33 are not available on Wednesdays. As can be seen the optimization process was able to adjust the schedule to accommodate these restrictions with a new schedule that does not assign Monday slots to patients 9 and 17, Tuesday slots to patients 18 and 30, and Wednesday slots to patients 5 and 33 on any of the machines in the clinic.

Table 2. Optimal schedule of the dialysis unit during the summer days accommodating restrictions on patients 5, 9,17, 18, 30, and 33.

	M	T	W	Th	F	S
Machine A	10,29	10,25	17,25	4,26	16,20	2,11
Machine B	22,26	16,23	18,20	5, 17	4,8	8,21
Machine C	12,14	26,28	15,28	32,35	18,36	5,35
Machine D	30,31	33,36	8,21	24,33	3,15	16,17
Machine E	19,34	2,5	6,22	12,18	14,24	3,27
Machine F	3,33	9,24	27,30	1,15	9,19	6,7
Machine G	25,32	4,20	2,23	9,11	1,36	13,36
Machine H	7,11	27,31	10,14	19,23	21,29	22,34
Machine I	6,13	29,32	1,13	7,34	12,30	28,31

Table 3 shows an additional requirement on the scheduling assignments that a patient cannot be assigned on two consecutive days. This is medically more convenient for the patients so that they can rest one day between their visits to the clinic.

Table 3. Optimal schedule of the dialysis unit during the busy summer days and requiring that patients do not perform dialysis on two consecutive days.

	M	T	W	Th	F	S
Machine A	1,2	3,4	1,2	3,4	1,2	3,4
Machine B	5,6	7,8	5,6	7,8	5,6	7,8
Machine C	9,10	11,12	9,10	11,12	9,10	11,12
Machine D	13,14	15,16	13,14	15,16	13,14	15,16
Machine E	17,18	19,20	17,18	19,20	17,18	19,20
Machine F	21,22	23,24	21,22	23,24	21,22	23,24
Machine G	25,26	27,28	25,26	27,28	25,26	27,28
Machine H	29,30	31,32	29,30	31,32	29,30	31,32
Machine I	33,34	35,36	33,34	35,36	33,34	35,36

The following figures represent the daily schedule for nurses and patients based on the optimal schedule of Table 3. Each nurse will oversee preparing three patients, with each taking approximately 15 minutes. Then, the patient will undergo a 3-hour treatment time, followed by a 30-minute cleaning process. There is also a 15-minute buffer time (after the nurse finishes cleaning their third and final machine) included to account for the nurses switching shifts midway through the day. Figure 5 represents these details in the schedule for Monday, Wednesday, and Friday while Figure 6 represents the schedule details for Tuesday, Thursday, and Saturday.

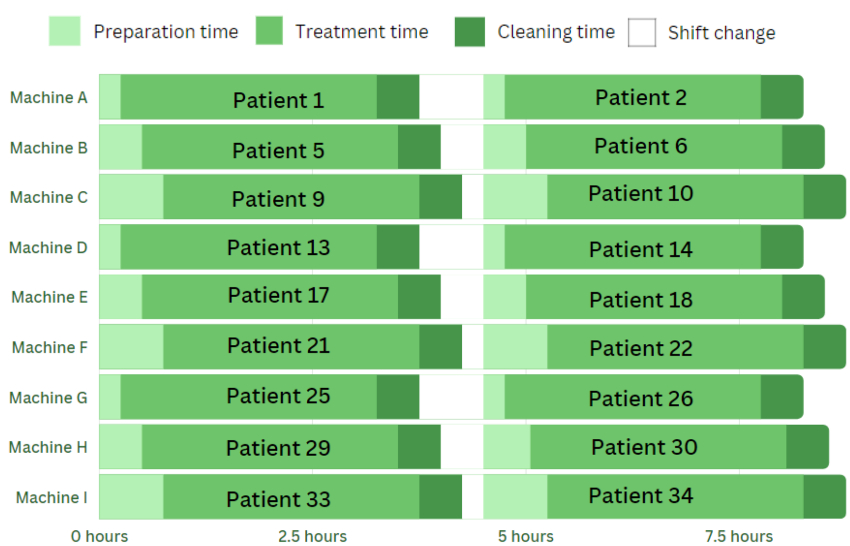

Figure 5. Optimal detailed treatment schedule – Monday, Wednesday, Friday.

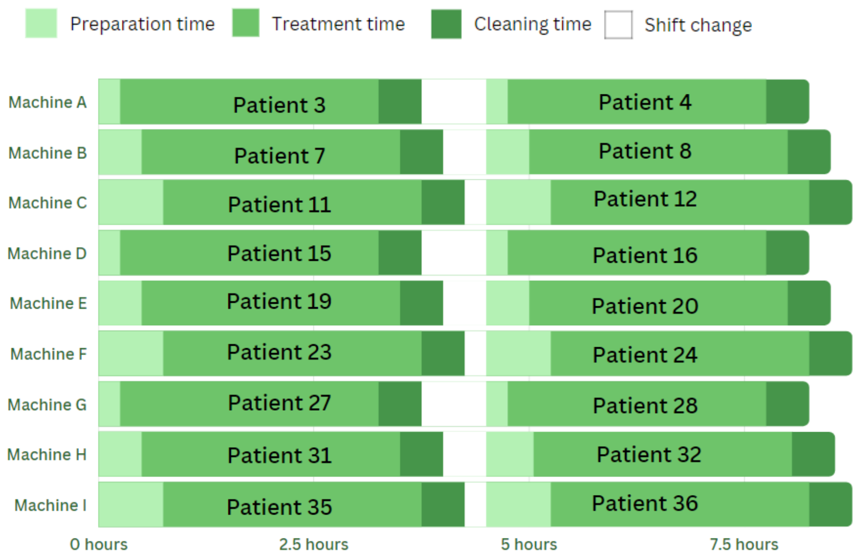

Figure 6. Optimal detailed treatment Schedule – Tuesday, Thursday, Saturday

Lastly, Table 4 is a run with 27 patients to illustrate the assignment of 27 patients during the non-busy days outside of the summer months.

Table 4. Optimal schedule of the dialysis unit during the normal non-summer days and requiring that patients do not perform dialysis on two consecutive days.

	M	T	W	Th	F	S
Machine A	1,2	3,4	1,2	3,4	1,2	3,4
Machine B	5,6	7,8	5,6	7,8	5,6	7,8
Machine C	9,10	11,12	9,10	11,12	9,10	11,12
Machine D	13,14	15,16	13,14	15,16	13,14	15,16
Machine E	17,18	19,20	17,18	19,20	17,18	19,20
Machine F	21,22	23,24	21,22	23,24	21,22	23,24
Machine G	25,26	27,	25,26	27,	25,26	27
Machine H	-	-	-	-	-	--
Machine I	-	-	-	-	-	-

5. Conclusion

In this paper, an optimization strategy was proposed to enhance nurse and dialysis unit scheduling, resulting in improved care for patients. This study demonstrates that optimizing nurse and dialysis unit scheduling can successfully accommodate the increasing number of patients in need of hemodialysis while ensuring timely and accessible care. An integer programming model was prepared for this purpose. The objective function of the model was to minimize dialysis times, and this was achieved by scheduling all patients three times per week, as per the requirement, as well as ensuring that the patients are given enough time to bleed if necessary while considering cleaning, preparation, and shift times. Further development of this study could include collecting data based on patient availability and performing the optimization based on this availability. During our optimization, the aim was to minimize the number of machines used, and the minimum number of machines required to schedule 36 patients for three sessions in a week was 9. Three machines are kept on standby in case of breakdowns, and maintenance is kept out of the summer months, so we are not losing a machine while we have more patients. During the other months of the year, there are only 27 patients, meaning, since the current unit capacity was shown to accommodate the busy summer months, it can therefore handle the less busy months throughout the year. The approach presented in this paper involves strategic resource management, maintaining appropriate staffing levels, and implementing efficient scheduling systems that prioritize patient needs. The mathematical programming model presented in this paper has been designed as a deterministic problem, disregarding uncertainties at this stage. Future work will consider the incorporation of various uncertainties, such as uncertainties related to patient no-shows, late arrivals, and unpredictable durations for dialysis treatments.

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Biographies

Bedis Elkamel is affiliated with the University of Central Florida Department of Health Sciences. With a multifaceted range of interests, he has devoted his expertise to the areas of nutrition and health, sports, and scientific research, with a particular focus on exploring the fascinating intersection of these fields. Bedis demonstrates a deep passion for understanding the impact of nutrition on overall health and well-being. Bedis has a keen interest in sports and their profound influence on physical fitness and performance. Bedis Elkamel's research pursuits are fueled by a strong commitment to scientific inquiry and discovery.

Abdennaceur Fgaier is a highly accomplished medical professional currently serving as a medical doctor at the prestigious Hôpital Régional Salim El-Hadhri De Kerkennah in Tunisia. With a strong academic background, he obtained his Medical Doctor (MD) degree from the renowned University of Sfax, where he acquired a solid foundation in the field of medicine. Recognizing the critical importance of specialized care for patients undergoing hemodialysis, Abdennaceur pursued further education and successfully obtained a specialization in hemodialysis. This additional expertise allows him to provide comprehensive and specialized care to patients with kidney-related conditions, ensuring their well-being during the hemodialysis process. Dr. Fgaier holds the position of general manager of the dialysis unit at Hôpital Régional Salim El-Hadhri De Kerkennah. In this capacity, he demonstrates his commitment to optimizing patient care and enhancing the overall operations of the dialysis unit. Abdennaceur's managerial role involves overseeing the daily operations, coordinating the scheduling of patient treatments, ensuring proper staffing levels, and maintaining the highest standards of care and safety within the unit.

Anis Mekki is a recent graduate of the MD Program at the University of Sfax, currently pursuing his residency. As part of his training, he is completing a rotation at the Dialysis unit at Hôpital Régional Salim El-Hadhri De Kerkennah. During this rotation, Anis is gaining hands-on experience in the field of nephrology, providing compassionate care to patients undergoing hemodialysis treatments. This valuable experience allows him to further develop his clinical skills, expand his knowledge of kidney-related conditions, and contribute to the team's efforts in optimizing patient care.