EFFECT OF HEMODIALYSIS ON INDIVIDUAL HANDWRITING CHARACTERISTICS IN A SAMPLE OF END-STAGE RENALDISEASE PATIENTS: MEDICO-LEGAL VIEW

BY

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ABSTRACT

Background: Handwriting is a skill that needs the integration of musculoskeletal and nervous actions. It could be affected by debilitating diseases like end-stage renal disease. Hemodialysis patients are at increased risk for cognitive impairment, psychological deficiencies, and metabolic changes which can influence the quality of handwriting. **Aim of work:** To investigate the effect of hemodialysis in a sample of end-stage renal disease patients on their handwriting. **Patients and methods:** This study included 110 end-stage renal disease patients on hemodialysis. They wrote two samples, one before and one after hemodialysis sessions with the unification of writing materials. Their handwriting was examined for word size, word spacing, and the pressure of writing, slanting direction of words, types of strokes, and overwriting. **Results:** among the studied patients, males were 61.8% and females were 38.2%. Most patients (70%) were on regular hemodialysis for less than 10 years. After hemodialysis 40.9% of the patients had increased word size, 14.5% had increased word spacing, 10.9% had weaker pressure of writing than before hemodialysis, and 44% showed strokes and overwriting. Extra strokes were the most common type that appeared after hemodialysis (25.5%). There were no significant associations between the presence of other concomitant diseases or the duration of hemodialysis and all the studied individual handwriting characteristics. Whereas increased word size and overwriting after hemodialysis were significantly higher in patients with medium-level education in comparison to other education levels. **Conclusion:** Hemodialysis therapy could affect patients' handwriting characteristics to a certain degree regardless of the duration of end-stage renal disease.

Keywords: *Forensic document examination, forgery, renal failure, hemodialysis, forensic science.*

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INTRODUCTION

Handwriting can be defined as the construction of letters, characters, and sometimes symbols with a writing instrument in an identifiable pattern that is intended to communicate with another person ***(Desai, 2013)***.Handwriting is a compound performance requiring a highly developed proficiency ***(Koppenhaver, 2007)***. It is a result of the integrated body's musculoskeletal and nervous actions, as well as the conscious and subconscious minds ***(Siegel, et al., 2013)***. There are two fundamental tenets of handwriting, one of which is that no two persons write the same in an extended handwriting sample. The other is that there is inherent variance in all writing, therefore no two writing samples from the same writer will ever be precisely alike ***(Koppenhaver, 2007; Stewart, 2017)***.

Handwriting is changeable, the writer's level of graphic maturity, the setting in which they are writing, the substrate, the writing instrument, their physical, mental, and emotional condition, their use of medicine, and other circumstances can all have an impact on their handwriting ***(Hicklin et al., 2022)***.These effects permeate the writer's entire life and contribute to the development of their individual style of handwriting ***(Koppenhaver, 2007)***.

Some neurodegenerative diseases such as Parkinson's disease, Alzheimer's disease, and Huntington's disease have been observed to have an impact on a person's handwriting. Long-term incapacitating conditions, like cancer, can also cause handwriting to

gradually deteriorate ***(Koppenhaver, 2007; Mohamed et al., 2016)***.

Another known debilitating disease is end-stage renal disease which is characterized by a decline in kidney filtration rate and loss of its regulatory, excretory, and endocrine activities ***(Silva et al., 2016)***. The aberrant clinical, metabolic, and hormonal manifestations that come along with renal failure are referred to as uremia or uremic syndrome. Diagnosis of uremic syndrome occurs when the renal glomerular filtration rate (GFR) drops to 15 ml/min or below ***(Hamed, 2019)***. In general, patients with chronic kidney disease (CKD) and end-stage renal disease (ESRD) frequently experience neurologic complications, such as encephalopathy, seizures, asterixis, cognitive impairment, cranial neuropathy, myopathy, peripheral neuropathy, extrapyramidal movement disorders including dystonia, parkinsonism, and chorea ***(Arnold et al., 2016)***. In individuals with kidney failure, neurologic problems are a major cause of morbidity and mortality ***(Hamed, 2019)***.Movement abnormalities in individuals with end-stage renal disease might emerge because of encephalopathy, medication, or structural defects. Asterixis or flapping tremors are two examples of involuntary movements that can occur in metabolic encephalopathy ***(Mohamed et al., 2016)***.

A permanent renal replacement therapy, such as hemodialysis (HD) treatment, is necessary for ESRD patients to survive ***(Silva et al., 2016)***. This HD therapy typically consists of three HD sessions per week, each lasting about 4 hours, to remove salt, waste, and extra water to prevent them from building up in the body. It also maintains a safe level of specific chemicals in the blood (like sodium, potassium, and bicarbonate) to help control blood pressure ***(Magnard et al., 2015)***.

Hemodialysis patients are at higher risk than only chronic kidney disease for medical conditions that are specifically linked to HD treatment, such as hypotension related to dialysis, post-dialysis fatigue, dialysisdisequilibrium syndrome, dialysis encephalopathy, myopathy, anemia, metabolic acidosis, metabolic alternations, catheter-related infection, and dialysis-related arrhythmias ***(Soangra et al., 2013)***. It has been observed that hemodialysis patients have a distinctive impairment in handwriting abilities, which may suggest a degree of cognitive deficiency that clinical examination and investigations cannot elicit. These variations may have important medicolegal significance and should be noted while examining their handwriting ***(Mohamed et al., 2016)***.

AIM OF THE WORK

Prior studies focused on the effects of neurodegenerative disorders and their implications on handwriting changes. Therefore, this study investigated the effect of hemodialysis therapy on individual handwriting characteristics in a sample of end-stage renal disease patients.

SUBJECTS AND METHODS

I. The study setting:

This is a prospective study that was conducted at the hemodialysis unit at Ismailia Medical Complex from 25 February to 24 March 2023.

II. Subjects:

This study included 110 patients with end-stage renal disease on regular three times weekly hemodialysis at the hemodialysis unit at Ismailia Medical Complex.

- Inclusion criteria: patients included in this study were aged 18 years and above from both genders, generally stable, and possess a primary level of education that guarantees their ability to read and write.
- Exclusion criteria: subjects were excluded from this study if they were less than 18 years old, illiterate, had a trauma affecting their handwriting, were taking any psychotropic substances or suffered its withdrawal, suffering from acute renal failure, or any acute condition affecting the patient's general stability or necessitating an urgent hemodialysis session.

III. Methods:

The participants' handwriting samples were collected in the Arabic language in a pre-formed exemplar designed by the researchers **(Figure 1)**. The information requested to be written in the exemplar by the participants included date of birth, gender, residence (rural or urban), occupation, level of education, duration of hemodialysis, other concomitant

diseases, handedness, and a part of the Egyptian national anthem. All participants were asked to write these data twice, one time before the session of hemodialysis and the second time after the hemodialysis session. Patients were given a one-hour interval between hemodialysis and the second writing to give them a chance to regain their power. Unified writing materials were used by all participants such as papers, pens, and supporting clipboards, making it easier to estimate the subtle changes in handwriting traits.


- تاريخ الميلاد: .....
- النوع (ذكر/ أنثى): .....
- مكان إقامتك (الحضر / الريف): من فضلك أكتب **حضر أو ريف** فقط وليس العنوان
- الوظيفة: .....
- مدة ممارسة هذه الوظيفة: .....
- المؤهل الدراسي: .....
- منذ متى بدأت الغسيل الكلوي: .....
- عدد مرات الغسيل أسبوعيا: .....
- أذكر الأمراض الأخرى التي تعاني منها: .....
- هل تكتب باليد اليمنى أم اليسرى: .....
- من فضلك أعد كتابة هذه الجملة:

بلادي بلادي بلادي لك حبي وفؤادي
مصر يا أم البلاد أنت غايتي والمراد
وعلي كل العباد كم لنيلك من أيادي

Figure (1): The requested exemplar for handwriting.

Handwriting assessment:

The samples of the handwriting of each participant were examined manually by an expert from the Forensic Medicine Authority, Egyptian Ministry of Justice with the aid of magnifying hand lenses in addition to the essential naked eye document examination in daylight. Both handwriting samples for each participant (before and after hemodialysis) were examined for word size, word spacing, the pressure of writing, slanting direction of words, types of strokes, and overwriting ***(Basalah, 2001)****;* any change in these features discovered in the second sample taken after the hemodialysis was recorded on a hard copy spreadsheet for subsequent statistical analysis.

Ethical considerations:

Ethical approval was obtained from the Research Ethics Committee (REC) of the Faculty of Medicine, Suez Canal University, Egypt ***(Reference number: 5220)*** following the Declaration of Helsinki for human studies *(WMA-The World Medical Association-WMADeclaration of Helsinki, 2008).*Informed consent was obtained from all participants before participation in the research. They were informed about the purpose of the research and were given the right to refuse participation or withdrawal at any time. Confidentiality of the participants' data was kept throughout the study as there was neither identifiable information nor any signature in the exemplars of participants' handwriting samples. The contact details of one of the research team were supplied to the participants for any explanation or inquiries.

STATISTICAL ANALYSIS:

Data analysis was performed with the statistical package for social science (SPSS), IBM Corporation, Chicago, USA software version 26. Descriptive statistics were used for summarising data. Qualitative data were represented as frequencies (n) and percentages (%). The chi-square test was used to determine the association between the independent variables (concomitant diseases, level of education, and duration of hemodialysis) and the dependent variables (word size, word spacing, slanting direction of words, types of strokes, and overwriting). A P-value of<0.05 was used to determine statistical significance ***(Charan and Biswas, 2013)***.

RESULTS

Table (1) shows the personal and demographic data of one hundred and ten studied end-stage renal disease patients on hemodialysis. Male patients represented most of the cases (61.8%). Data showed that (24.5%) of patients were in the age group of 41-50 years. The education level of almost half of the studied patients (48.2%) was medium education. Patients who don't work were (44.5%). Approximately (98%) of patients were right-handed. As regards the different durations of hemodialysis among the studied patients, most patients (70%) are on regular hemodialysis for less than 10 years **(Figure 2)**. Cardiovascular diseases were the most concomitant diseases (43.6%) experienced by the studied end-stage renal disease patients **(Figure 3)**.

Regarding the changes in handwriting characteristics among studied patients with end-stage renal disease after hemodialysis it showed that 40.9% of patients had increased word size and 14.5% had increased word spacing, while only 10.9% had weaker pressure of writing than before hemodialysis **(Table 2)**. 44% of patients displayed different strokes and overwriting after hemodialysis. Exploring different types of handwriting strokes and overwriting revealed that 25.5% of patients had extra strokes in their handwriting, followed by 20.9% of them displaying overwriting, and 18.2% having handwriting-interrupted strokes **(Figure 4)**. Different samples showed examples of the changes in handwriting characteristics in some end-stage renal disease patients after hemodialysis **(Figures 5 - 8)**.

Regarding the association of the absence or presence of other concomitant diseases with different handwriting characteristics in the studied patients after hemodialysis, more than half or nearly half percentage of the studied patients who had almost all different changes in handwriting characteristics also had other concomitant diseases.

On the other hand, there was no significant difference between the presence or absence of other concomitant diseases and all different handwriting characteristics in the studied patients after hemodialysis **(Table 3)**.

Regarding the association of the level of education with different handwriting characteristics in the studied patients after hemodialysis, more than half or nearly half percentage of the patients who had almost all different changes in handwriting characteristics also had medium education in comparison to other education levels. On the other hand, there was a significant difference only between patients who manifested increased word size and overwriting in their handwriting after hemodialysis and their levels of education **(Table 4)**.

Regarding the association of hemodialysis duration with different handwriting characteristics in the studied patients after hemodialysis, more than half or half a percentage of the patients who had almost all different changes in handwriting characteristics were under the treatment of hemodialysis for less than 10 years. On the other hand, there was no significant difference between the duration of hemodialysis and all different handwriting characteristics in the studied patients after hemodialysis **(Table 5)**.

Table (1): Personal and demographic data of the studied end-stage renal disease patients on hemodialysis (N=110).

Variable		Frequency	Percent (%)
Gender	Male	68	61.8
	Female	42	38.2
Age	18-30 years	15	13.6
	31-40 years	23	20.9
	41-50 years	27	24.5
	51-60 years	22	20
	More than 60 years	23	20.9
Residence	Urban	46	41.8
	Rural	64	58.2
Education	Below medium	26	23.6
	Medium	53	48.2
	High (bachelor's degree)	31	28.2
Occupation	Employee	27	24.5
	Worker	8	7.3
	Farmer	4	3.6
	Free Business	8	7.3
	Retired	7	6.4
	Student	7	6.4
	Don't work	49	44.5
Handedness	Right-handed	108	98.2
	Left-handed	2	1.8

N= total number.

Table (2): Frequency of change in handwriting characteristics among the studied end-stage renal disease patients after hemodialysis (N=110).

Characteristic		Frequency	Percent (%)
Word size	No change	65	59.1
	Increased word size	45	40.9
Word spacing	No change	94	85.5
	Increased word spacing	16	14.5
Pressure of writing	No change	98	89.1
	Weak	12	10.9
Slanting direction of words	No change	101	91.9
	Left upward	4	3.6
	Left downward	4	3.6
	Zigzag	1	0.9

N= total number.

Table (3): Association of absence or presence of concomitant diseases with different handwriting characteristics in the studied end-stage renal disease patients after hemodialysis (N=110).

Concomitant diseases		Absent (N=47)		Present (N=63)		χ^2	P-value
Characteristic		**n**	**%**	**n**	**%**		
Word size	No change	23	35.4%	42	64.6%	3.501	0.061
	Increased word size	24	53.3%	21	46.7%		
Word spacing	No change	40	42.6%	54	57.4%	0.008	0.929
	Increased word spacing	7	43.8%	9	56.3%		
Pressure of writing	No change	41	41.8%	57	58.2%	0.291	0.589
	Weak	6	50%	6	50%		
Slanting direction of words	No change	41	40.6%	60	59.4%	3.317	0.345
	Left upward	3	75%	1	25%		
	Left downward	2	50%	2	50%		
	Zigzag	1	100%	0	0%		
Types of strokes and overwriting	Interrupted stroke	8	40%	12	60%	0.074	0.785
	Curved or Stiff stroke	5	33.3%	10	66.7%	0.626	0.429
	Recurrent stroke	7	50%	7	50%	0.347	0.556
	Extra stroke	13	46.4%	15	53.6%	0.210	0.647
	Overwriting	12	52.2%	11	47.8%	1.060	0.303

N= total number, n= number, N= number of patients in subgroups of concomitant diseases.
*χ^2Chi-square analysis, *Significance at p<0.05.*

Table (4): Association of the level of education with different handwriting characteristics in the studied end-stage renal disease patients after hemodialysis (N=110).

Level of education		Below medium (N=26)		Medium (N=53)		High (N=31)		χ^2	P-value
Characteristic		**n**	**%**	**n**	**%**	**n**	**%**		
Word size	No change	14	21.5%	27	41.5%	24	36.9%	6.059	**0.048***
	Increased word size	12	26.7%	26	57.8%	7	15.6%		
Word spacing	No change	20	21.3%	46	48.9%	28	29.8%	2.190	0.335
	Increased word spacing	6	37.5%	7	43.8%	3	18.8%		
Pressure of writing	No change	20	20.4%	50	51%	28	28.6%	5.511	0.064
	Weak	6	50%	3	25%	3	25%		
Slanting direction of words	No change	22	21.8%	48	47.5%	31	30.7%	7.646	0.265
	Left upward	1	25%	3	75%	0	0%		
	Left downward	2	50%	2	50%	0	0%		
	Zigzag	1	100%	0	0%	0	0%		
Types of strokes and overwriting	Interrupted stroke	8	40%	10	50%	2	10%	5.653	0.059
	Curved or Stiff stroke	5	33.3%	8	53.3%	2	13%	2.145	0.342
	Recurrent stroke	5	35.7%	6	42.9%	3	21.4%	1.344	0.511
	Extra stroke	6	21.4%	15	53.6%	7	25%	0.439	0.803
	Overwriting	3	13%	17	73.9%	3	13%	7.741	**0.021***

N= total number, n= number, N= number of patients in subgroups of the level of education.
*χ^2 Chi-square analysis, *Significance at p<0.05.*

Table (5): Association of the hemodialysis duration with different handwriting characteristics in the studied end-stage renal disease patients after hemodialysis (N=110).

Duration of hemodialysis		Less than 10 years (N=77)		From 10 - 20 years (N=30)		More than 20 years (N=3)		χ^2	P-value
Characteristic		n	%	n	%	n	%		
Word size	No change	48	73.8%	17	26.2%	0	0%	4.742	0.093
	Increased word size	29	64.4%	13	28.9%	3	6.7%		
Word spacing	No change	62	66%	29	30.9%	3	3.2%	5.054	0.08
	Increased word spacing	15	93.8%	1	6.3%	0	0%		
Pressure of writing	No change	66	67.3%	29	29.6%	3	3.1%	3.042	0.218
	Weak	11	91.7%	1	8.3%	0	0%		
Slanting direction of words	No change	71	70.3%	27	26.7%	3	3%	6.784	0.341
	Left upward	1	25%	3	75%	0	0%		
	Left downward	4	100%	0	0%	0	0%		
	Zigzag	1	100%	0	0%	0	0%		
Types of strokes and overwriting	Interrupted stroke	17	85%	3	15%	0	0%	2.802	0.246
	Curved or Stiff stroke	12	80%	3	20%	0	0%	1.059	0.589
	Recurrent stroke	7	50%	7	50%	0	0%	4.392	0.111
	Extra stroke	18	64.3%	10	35.7%	0	0%	2.181	0.336
	Overwriting	16	69.6%	7	30.4%	0	0%	0.901	0.637

N= total number, n= number, N= number of patients in subgroups of the duration of hemodialysis.
*χ^2 Chi-square analysis, *Significance at p<0.05.*

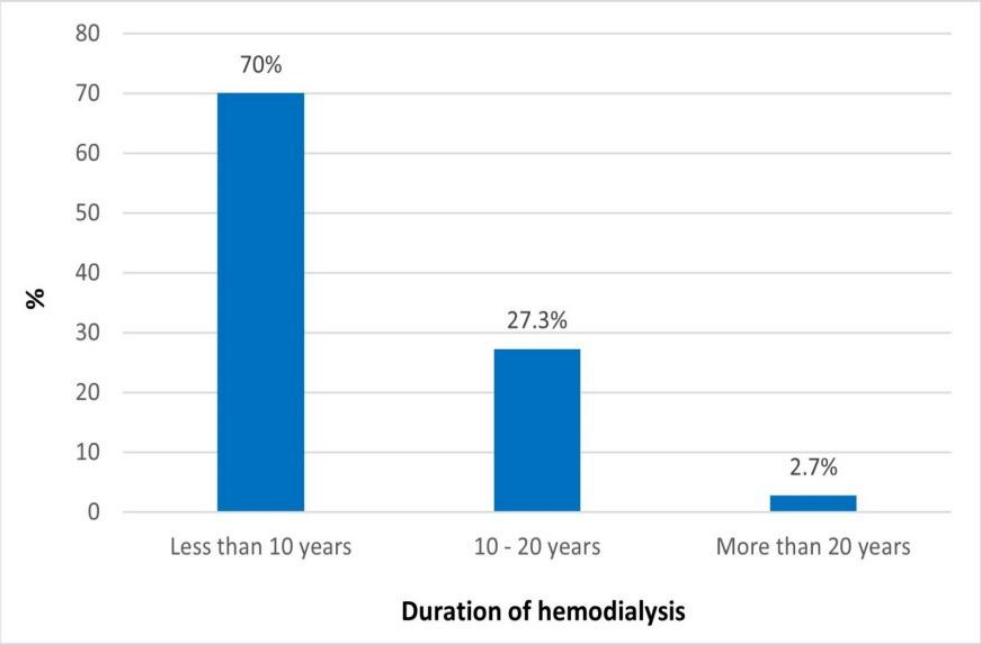


Figure (2): Duration of hemodialysis among the studied end-stage renal disease patients on hemodialysis (N=110).

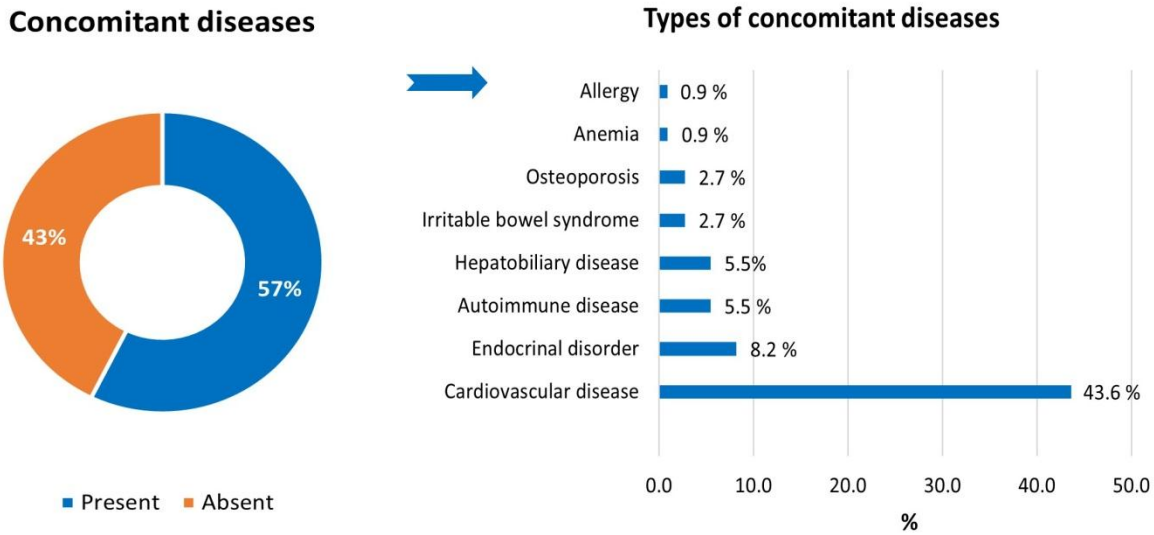


Figure (3): Concomitant diseases experienced by the studied end-stage renal disease patients on hemodialysis (N=110).

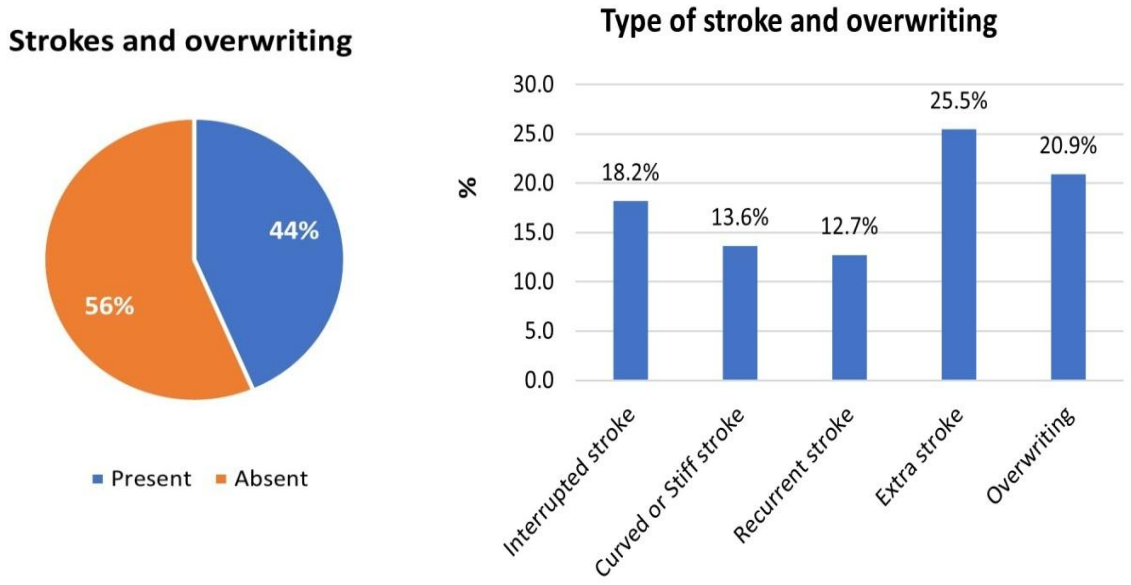
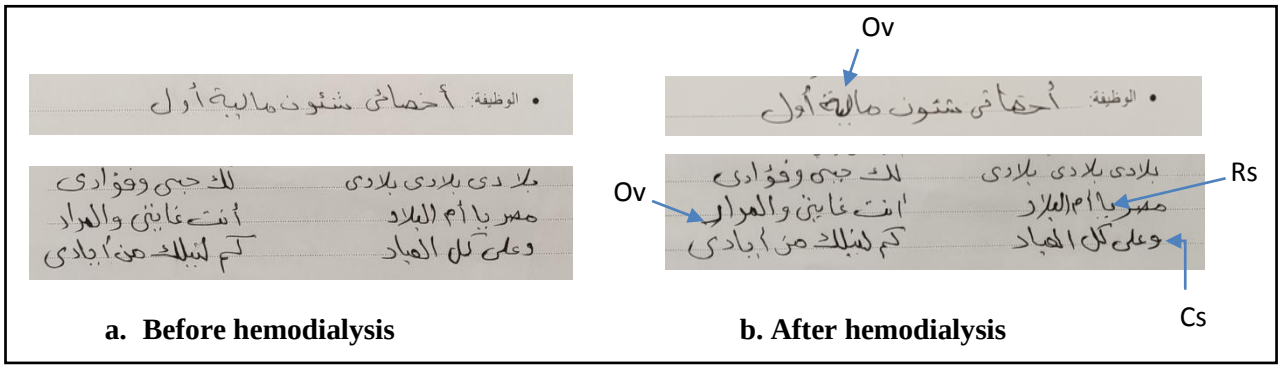
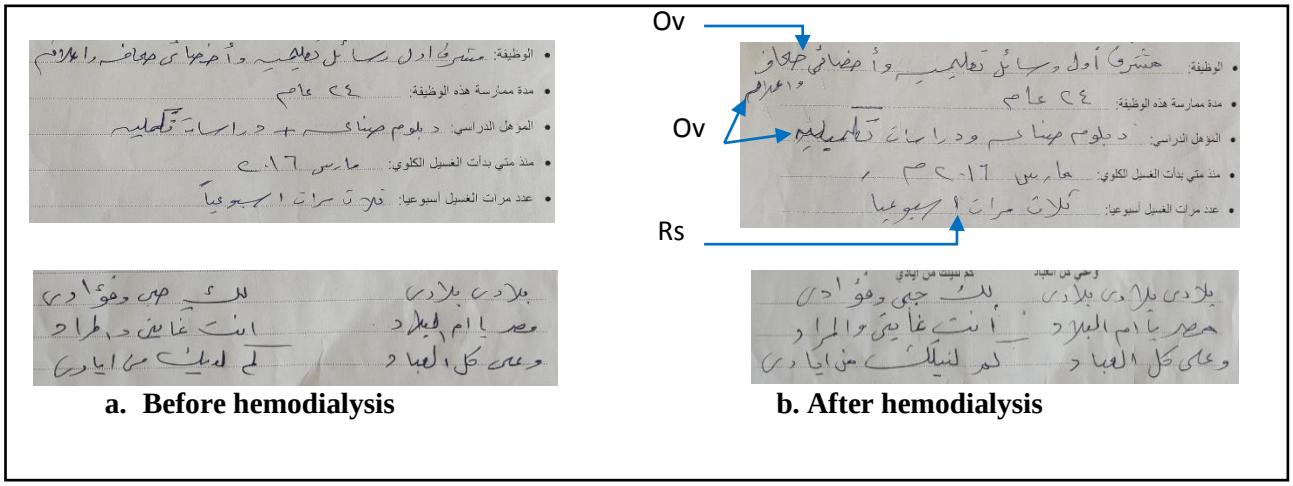


Figure (4): Handwriting strokes and overwriting appeared among the studied end-stage renal disease patients after hemodialysis (N=110).



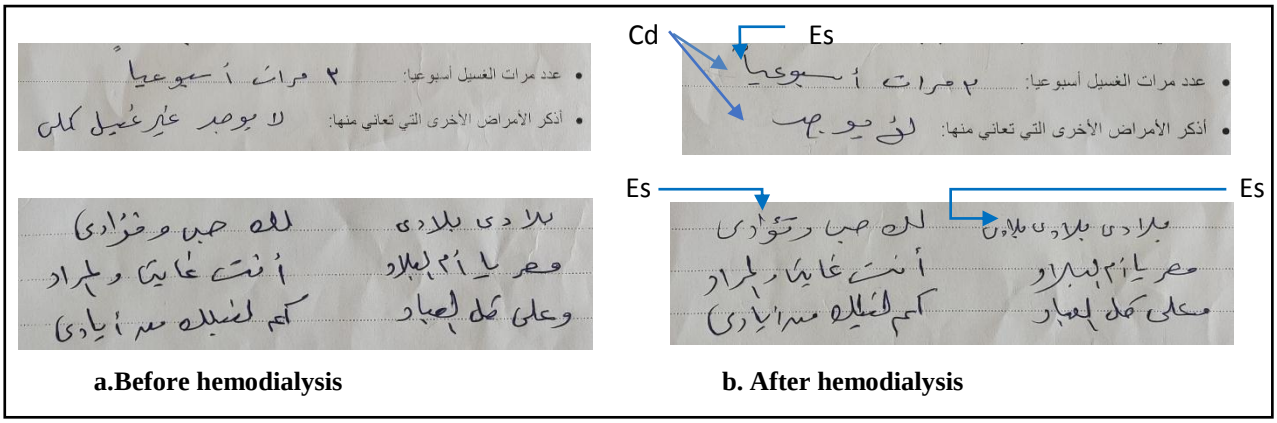
a. Before hemodialysis **b. After hemodialysis**

Figure (5): Samples of handwriting for a 41-year-male patient with high education level before and after the hemodialysis session showing overwriting (Ov), recurrent strokes (Rs), and curved strokes (Cs) after hemodialysis.



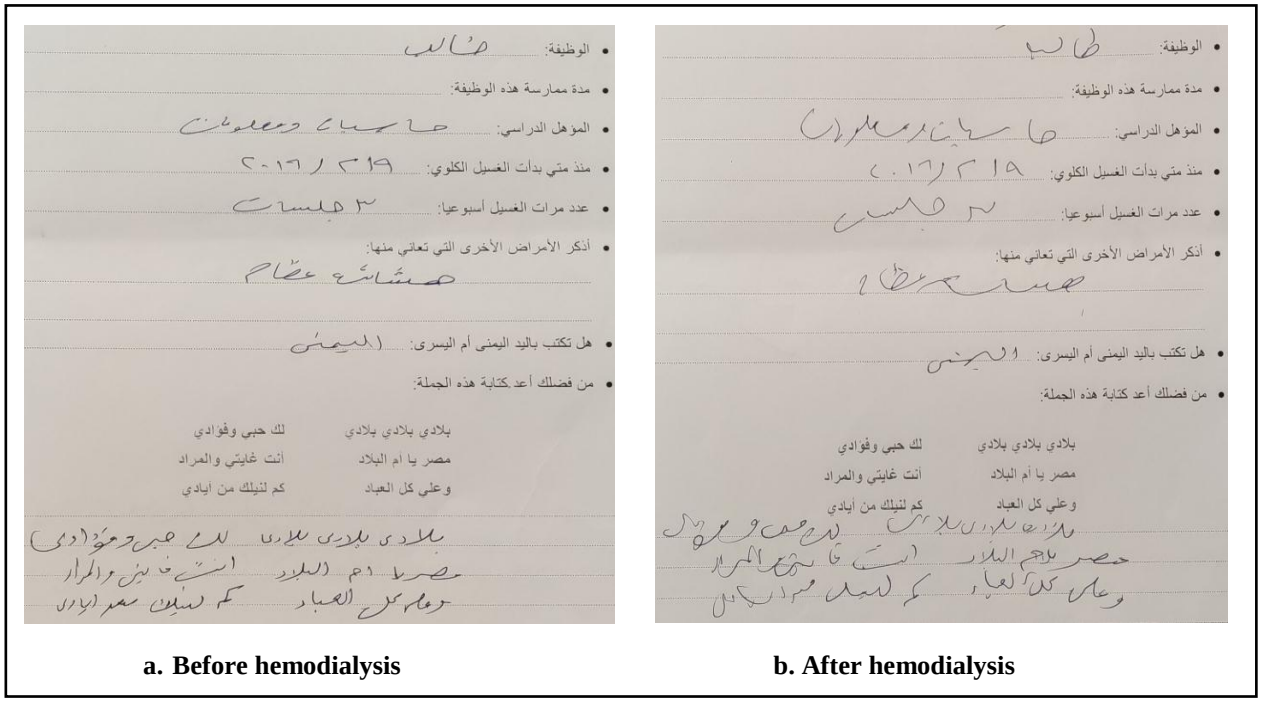
a. Before hemodialysis **b. After hemodialysis**

Figure (6): Samples of handwriting for a 54-year-male patient withmedium education level before and after the hemodialysis session showing overwriting (Ov), recurrent stroke (Rs), and increased word size after hemodialysis.



a.Before hemodialysis **b. After hemodialysis**

Figure(7): Samples of handwriting for a 57-year-male patient with medium education level before and after the hemodialysis session showing extra strokes (Es) andchange in direction of writing to left upward (Cd) after hemodialysis.



a. Before hemodialysis **b. After hemodialysis**

Figure (8): Samples of handwriting for a 25-year-male patient with high education level before and after the hemodialysis session showing general weakness of writing after hemodialysis.

DISCUSSION

Based on this cross-sectional study of patients with end-stage renal disease who were on regular hemodialysis, the main question was if hemodialysis therapy has any effect on their handwriting characteristics. The results of this study indicate that hemodialysis treatment can affect the patients' handwriting features regardless of the duration of end-stage renal disease. Several hypotheses on the analysis of hand movements argue that motor and cognitive abilities are closely related. Among the most common handwriting characteristics used to distinguish between samples of healthy individuals and patients with different cognitive problems are kinematic features ***(Moetesum et al., 2022; Nicolas et al., 2013)***. Therefore, the focus of this work was on the variation that could be observed in patients' handwriting across the window that extends just before and after hemodialysis, as previous researchers have demonstrated that general

cognitive ability changes considerably throughout the dialysis session, with the poorest performance during the session and highest just before or the day that follows ***(Owolabi et al., 2016).***

The findings of our study should assist forensic document experts while solving similar cases by considering that hemodialysis alone might cause further alterations in handwriting characteristics, regardless of the impact of chronic kidney disease.

In the current study, patients' analyzed handwriting characteristics changed after hemodialysis; 40.9% of the patients had increased word size, 14.5% had increased word spacing, and only 10.9% had weaker pressure of writing than before hemodialysis. Studying various handwriting strokes and overwriting patterns revealed that 25.5% of patients had extra strokes, followed by 20.9% who showed overwriting, and 18.2% who had interrupted strokes. These results were consistent with those of ***Mohamed et al., (2016)***, who examined the handwriting characteristics of 37 stable Egyptian hemodialysis patients to determine how they had changed from their handwriting before the disease. Their findings showed that 46% of hemodialysis patients had large word size, 97.3% had increased word spacing, 62.2% used light pressure when writing, 100% had extra strokes, 97.3% had interrupted strokes, and 73% showed overwriting.

Neurological problems are often experienced by patients with chronic kidney disease (CKD). Several factors, including the build-up of uremic toxins, metabolic and hemodynamic issues, oxidative stress, inflammation, impaired blood-brain barrier, and the anatomical similarity between the kidneys and the brain.—both of which are low resistance end organs subjected to high blood flow—contribute to the neurological disorders in CKD. Both the peripheral and the central nervous systems are affected by neurological diseases in CKD. Somatic and cranial peripheral neuropathies, as well as myopathy, are the causes of the peripheral neurological symptoms of CKD. Cortical or subcortical lesions are the cause of the central neurological symptoms of CKD. The cortical abnormalities of CKD are characterized by epileptic seizures, asterixis, encephalopathy, cognitive impairment, and cortical myoclonus ***(Arnold et al., 2016; Jabbari and Vaziri, 2018)***.

Our earlier results could be explained by hemodialysis (HD)-specific factors that are more relevant for the occurrence of cognitive impairment (CI). Due to reduced cerebral venous oxygen saturation and cerebral hypoperfusion, chronic intradialytic hypotension exposure has been associated with poor cognitive function in HD patients ***(Chai et al., 2020)***.

Moreover, hemodialysis patients are at risk for developing dialysis disequilibrium syndrome (DDS), an encephalopathy that worsens rapidly due to cerebral edema brought on by fluid and electrolyte imbalances ***(Mistry, 2019)***. Also, it's likely for HD patients to experience inflammatory reactions because of these abrupt physiological changes. Headaches, agitation, exhaustion, nausea, vomiting, impaired vision, tremors, and cramping are symptoms of the mild phase of DDS. This also negatively affects the patient's capacity for handwriting ***(Hamed, 2019; Patel et al., 2016)***.

Hemodialysis causes stress due to the numerous physical challenges associated with treatment, including the lengthy stay in HD facilities, and the dietary and daily fluid restrictions. However, the condition of dependence on healthcare, a dialysis machine, a transplanted organ, or family members is the main cause of stress due to hemodialysis ***(Lai et al., 2018)***. It has been suggested that variations in mood might have an impact on a person's handwriting ability. ***Rispler et al. (2018)***, observed that those in a negative mood wrote more slowly and had shorter strokes in both width and height than those in a neutral or positive mood. In a similar vein, depression in hemodialysis patients is quite prevalent***. Karakizlis et al. (2021)***, discovered depression to be substantially related to cognitive impairment and observed that it worsened over time following the last dialysis session.

The most noticeable handwriting change among the patients with chronic renal failure who underwent hemodialysis in the current research was an increase in word size (40.9%). Normal people are supposed to decrease their handwriting size to half its original size once they have mastered handwriting. The word spacing and writing proportion are spatially related to the size of the writing. Yet, the size of the writing may change depending on the circumstances ***(Koppenhaver, 2007).*** Dysgraphia could be induced by incorrect pen pressure, an inconsistent mean speed (too fast/slow), irregular changes in velocity and/or pauses, too frequent or long lifts, or large motions corresponding to macrography ***(Biotteau et al., 2022)***.

Saini and Kaur (2019), who claimed some of the writings by elderly people showed an increase in writing size, may explain the prior finding. Older persons were found to have uneven letter sizes across their signatures, which demonstrate a loss of pen control. Kinematic tests on the handwriting of elderly people also indicate that the size of their writing is not always consistent. This was consistent with the current study's subjects, who were primarily older than 40 (65.4%). The most significant indicator for cognitive decline is age, which is evident in individuals over the age of 35 and more commonly in those over the age of 65 in CKD patients ***(El Belbessi et al., 2018)***. Even at earlier ages than the general population, these elderly patients on hemodialysis are probably at significant risk of acquiring dementia and Alzheimer's disease (AD) with cognitive impairment ***(McAdams-DeMarco et al., 2018)***.

In discussing the potential risk of dementia in dialysis patients, two conditions have been recognized. Uremic encephalopathy, which includes oxidative stress, uremic toxins, and hormonal disturbance. Although this encephalopathy may respond to HD, it can present with tremors, multifocal myoclonus, and seizures. Dialysis encephalopathy syndrome, with symptoms of slurred speech, dysarthria, and myoclonic spasms, is brought on by aluminum toxicity. In patients undergoing hemodialysis, aluminum toxicity is a systemic condition. The main causes of aluminum toxicity include ingestion of phosphate binders containing aluminum by patients who are unable to eliminate it from their bodies, as well as exposure to aluminum in the dialysis fluid. This condition, which is today an uncommon incidence, was averted by minimizing the usage of aluminum hydroxide and treating phosphate deficiency ***(Patel et al., 2016)***.

According to the results of the current study, 10.9% of the studied patients had weaker pressure of writing than before hemodialysis. The level of physical and mental status is reflected in handwriting by pen pressure. Pressure is the term used to describe how firmly the hand is gripping the writing tool and how forcibly the pen is being pushed over the page. For various writers, it might be light to heavy ***(Rohym et al., 2021)***.

Light pressure demonstrates sensitivity to the environment and empathy for others, whereas heavy pressure denotes dedication and taking things seriously. The uremic myopathy, which affects patients with chronic kidney disease and causes proximal muscle weakness and muscle wasting, as well as the uremic peripheral neuropathy, which causes distal sensory loss that spreads to the distal upper extremity with disease progression, may be responsible for the results mentioned above ***(Arnold et al., 2016)***. In a similar vein, ***El-Najjar et al., (2014)***, reported hand dysfunction as an upper limb disability in HD patients. Furthermore, it has been discovered that during a dialysis session, sensory carpal tunnel syndrome symptoms including numbness, paresthesia, and pain worsen ***(Hamed, 2019)***.

In the present study, the change in the slant of writing (8.1%) was the most unaffected characteristic among the studied patients after hemodialysis. Slant or slope often refers to the direction in which the text is leaning. It might be vertical, to the right or left ***(Rohym et al., 2021)***. Slow writers often do not slant their writing as much to the right as fast writers, who tend to do it with solid, consistent strokes ***(Koppenhaver, 2007)***.

Our previous results could be interpreted with the findings of Mohamed et al. who reported that the highest percentage of the studied

hemodialysis patients showed a slow speed of their handwriting ***(Mohamed et al., 2016)***.

More than half of the patients in the current study who had the most changes in their handwriting following hemodialysis also had other comorbid conditions. Most co-occurring comorbidities (43.6%) among the patients with chronic renal failure in the study were cardiovascular diseases. Nevertheless, in the examined chronic renal failure patients following hemodialysis, there was no significant correlation between the presence or absence of other concurrent diseases and any of the various handwriting characteristics. These findings are inconsistent with ***Petrov et al. (2018)*** findings who found that cardiovascular diseases enhance the likelihood of handwriting deterioration in dentists who frequently stand leaning forward while working and that more than half of dentists with cardiovascular disorders experience it.

A possible reason for the differing results in our study is the possible cause of cardiovascular disease as previous research corresponds the cardiovascular manifestations detected in ESRD and CKD patients to autonomic dysfunction ***(Arnold et al., 2016)***. However, ***Petrov et al. (2018)***, attributed the cardiovascular diseases associated with handwriting deterioration in dentists who commonly stand leaning forward while working to the effect of this position on the musculoskeletal burden on the cervical spine which can cause cerebral tissue hypoxia in the brain areas responsible for regulating blood pressure and eventually leading to cervicogenic hypertension.

The current study found a significant correlation between patients' levels of education and the appearance of increased word size and overwriting in their handwriting after hemodialysis, with over half of the investigated patients exhibiting handwriting alterations having a medium level of education. These findings are consistent with those reported by ***Karakizlis et al. (2021)***, who examined the cognitive profile of hemodialysis patients and discovered that cognitive impairment is prevalent and is associated with medium levels of education in these individuals. Graphic maturity is achieved when the person's motor skills are completely developed, and they no longer need to focus on the process of writing. Writing skill development is influenced by education level. An uneducated writer uses awkward, sluggish strokes. As writing ability improves, the writing becomes smoother and more proficient. Some individuals never achieve graphic maturity. The quality of their writing remains poor if they do not need to do so. Moreover, a lack of formal education leads to poorly formed handwriting ***(Koppenhaver, 2007)***.

The current investigation revealed that most of the patients who exhibited changes in their handwriting characteristics after hemodialysis had been under therapy for less than ten years. Nevertheless, there was no correlation between the duration of hemodialysis and any of the examined handwriting characteristics.

Another study revealed an increased frequency of cognitive impairment that became noticeable within months after beginning HD, with the most deficits in verbal and reasoning skills, which may be related to shorter dialysis periods (12 months). Furthermore, those with mild cognitive impairment experienced the greatest deficits in memory and language with longer dialysis vintages (median 57 months), whereas those with severe cognitive impairment experienced the greatest deficits in attention and visuospatial abilities ***(Schorr et al., 2022)***.

Our earlier observations are inconsistent with ***Owolabi et al. (2016)***, who indicated that the duration of CKD, dialysis duration, and levels of urea and creatinine were the variables linked with psychomotor speed impairment. Attentiveness and concentration in the patients were correlated with dialysis duration and serum creatinine. Short-term memory decline was linked to aging, urea, and serum creatinine levels.

This discrepancy could be due to the different variables and methodologies assessed and used in both studies, as the basis in the current study is to assess the characteristics of the patients' typical handwriting by using pens and papers before and after hemodialysis sessions. While the other study assessed

patients' cognitive function only before dialysis treatments using a computer‑assisted neuropsychological test battery called Iron Psychology ("FePsy") ***(Owolabi et al., 2016)***.

While examining forensic documents, the examiner needs access to adequate information to accurately determine the documents' validity. The first step in evaluating the disputed document is to determine if a single person wrote the entire writing. Additionally, the examiner should consider evidence of the various pens used, along with other individual characteristics. The next step is to confirm that the writing is genuine and was not forged or copied. To do this, detailed information on the writer's physical, mental, and emotional status at the time the document in question was written—as well as whether they were dealing with any chronic illnesses—is required ***(Koppenhaver, 2007; Stewart, 2017)***.

A document's time of writing—whether it was done so before or after the disease began—may also be in question. In this context, experts require actual evidence to inform them of how handwriting alters in the presence of neurological conditions ***(Mohamed et al., 2016)***.

However, the present study has some limitations, including the inability to completely rule out the possibility of other coexisting diseases or conditions that may have had an impact on handwriting. A larger sample size might have been more informative, but dialysis patients are often exhausted after the long session; hence, we were limited to participants who agreed and were able to stay for one-hour post dialysis to be enrolled. The bias of the influence of education on the status of handwriting may have been reduced by using equal groups of patients with various educational backgrounds.

CONCLUSION

This study concluded that hemodialysis treatment brings about considerable effects on the handwriting characteristics of an individual including increased word size and spacing, weaker pressure of writing, and appearance of certain types of strokes in addition to overwriting. Level of education was found to be associated with the change of word size and appearance of overwriting after hemodialysis. While the duration of hemodialysis and the presence of other concomitant diseases were not significantly associated with any changes in the studied individual handwriting characteristics.

RECOMMENDATIONS

Forensic document examiners and forgery experts should pay extra attention during the analysis of questioned documents and/or handwriting of ESRD patients on hemodialysis. Taking into consideration the possible changes in handwriting characteristics before and after initiation of dialysis and throughout the progression of ESRD that might reflect the degree of competency and cognitive ability for decision-making and signing official documents.

- Further study, with a larger sample size and different parameters, shall be conducted on dialysis patients that would be more representative of any alteration of their handwriting.
- We recommend incorporating "Forensic Document Examination" in postgraduate curricula of Forensic Medicine and Toxicology in all Egyptian universities. In addition, carrying out repeated training for forensic experts on this issue to increase their knowledge and sharpen their skills regarding this critical aspect of forensic science.

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تأثيرغسيل الكلى على خصائص خط اليد الفردي في عينة من مرضى الكلى في المرحلة النهائية: نظرة طبية قانونية

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الملخص العربى

المقدمة:الكتابة اليدوية هي مهارة تحتاج إلى تكامل الحركات العضلية الهيكلية والعصبية. يمكن أن تتأثر بالأمراض المنهكة مثل مرض الكلى في المرحلةالنهائية. يتعرض مرضى غسيل الكلى لخطر متزايد للإصابة بالضعف الإدراكي والقصور النفسي والتغيرات الأيضية التي يمكن أن تؤثر على جودة الكتابة اليدوية. لذا فقد أجريت هذه الدراسة لتقييم تأثير غسيل الكلى في عينة من مرضى الكلى في المرحلة النهائيةعلى خط يدهم

طريقة البحث: تضمنت هذه الدراسة ١١٠ مريض مصاب بأمراض الكلى في المرحلة النهائيةوالذين يخضعون لغسيل الكلى. قاموا بكتابة عينتين ، واحدة قبل جلسات غسيل الكلى والأخرى بعد ذلك مع توحيد مواد الكتابة. تم فحص خط يدهم لمعرفة حجم الكلمات ، والمسافة بين الكلمات ، وضغط الكتابة ، والاتجاه المائل للكلمات ، وأنواع الجرات الخطية واعادة الكتابة على ما سبق كتابته.

النتائج: من بين المرضى الخاضعين للدراسة ، كان الذكور ٦١.٨٪ والإناث ٣٨.٢٪. كان معظم المرضى (٧٠٪) يخضعون لغسيل الكلى بانتظام لمدة تقل عن ١٠ سنوات. بعد غسيل الكلى زاد حجم الكلمات لدى ٤٠.٩٪ من المرضى ، وزاد ١٤.٥٪ من تباعد الكلمات ، و ١٠.٩٪ كان لديهم ضغط كتابة أضعف مما كان عليه قبل غسيل الكلى ، وأظهر ٤٤٪ جراتخطية واعادة الكتابة على ما سبق كتابته.الجرات الزائدة هي النوع الأكثر شيوعاً الذي ظهر بعد غسيل الكلى (٢٥.٥٪). لم تكن هناك ارتباطات ذات دلالة إحصائية بين وجود أمراض مصاحبة أخرى أو مدة غسيل الكلى وجميع خصائص خط اليد الفردية المدروسة. في حين أن زيادة حجم الكلمات واعادة الكتابة على ما سبق كتابته بعد غسيل الكلى كانت أعلى بشكل ملحوظ في المرضى ذوي المستوى التعليمي المتوسط مقارنة بمستويات التعليم الأخرى.

الخلاصة والتوصيات: يمكن أن يؤثر علاج غسيل الكلى على خصائص خط اليد للمرضى بشكل واضح بغض النظرعن مدة المعاناه من مرض الكلى. لذا يجب على خبراء وثائق الطب الشرعي إجراء تقييم دقيق لأي مستند يعود لمريض غسيل الكلى. مع الأخذ في الاعتبار التغييرات المحتملة في خصائص خط اليد قبل وبعد بدء غسيل الكلى وطوال تقدم الداء الكلوي بمراحله الأخيرة، كما نوصي بإجراء مزيد من الدراسة ، مع حجم عينة أكبر ومعايير مختلفة ، على مرضى غسيل الكلى التي من شأنها أن تكون أكثر تمثيلاً لأي تغيير في خط يدهم.علاوة على ذلك ، فإننانوصي بدمج "فحص الوثائق الجنائية" في مناهج الدراسات العليا للطب الشرعي وعلم السموم في جميع الجامعات المصرية ،إضافة إلى إجراء تدريب متكرر لخبراء الطب الشرعي بشأن هذه المسألة لزيادة معرفتهم وصقل مهاراتهم فيما يتعلق بهذا الجانب الحاسم لعلوم الطب الشرعي.