European Journal of Molecular & Clinical Medicine

ISSN 2515-8260 Volume 9, Issue 3, Winter 2022

ORIGINAL RESEARCH

Effect of Hemodialysis on pulmonary function in patients with End stage renal disease

[1]Shailendra Mane, [2]C Bhujbal, [3]Rajashri Mane, [4]Rajesh Khayalappa

[1]Associate Professor, [2]Post graduate, [4]Professor, Department of Medicine, Dr DY Patil Medical College & Research Center, Kasaba Bawada, Kolhapur, Maharashtra, India
[3]Professor, Department of ENT, Dr DY Patil Medical College & Research Center, Kasaba Bawada, Kolhapur, Maharashtra, India

Correspondence:
Shailendra Mane
Associate Professor, Department of Medicine, Dr DY Patil Medical College & Research Center, Kasaba Bawada, Kolhapur, Maharashtra, India
Email: hospitalvenkateshwara@gmail.com

ABSTRACT

Background: The intermittent hemodialysis (IHD) has been a useful renal replacement therapy for critically ill patients.Pulmonary dysfunction in end-stage kidney disease has been seen as a straight effect of circulating uremic toxins or a secondary effect of volume overload, anemia, immune suppression, premature airway closure, ventilation-perfusion mismatching, severe mechanical loading, gas transfer defects, malnutrition, electrolyte disorders, and/or acid/base imbalances.

Aim of the study: To study effect of Hemodialysis on pulmonary function in patients with end stage renal disease.

Materials and methods: The present study was conducted at Department of Medicine, D. Y. Patil Hospital, Kolhapur, Maharashtra.We sampled all the hemodialysis patients from four selected units that met the inclusion and exclusion criteria.

Results: A prospective observational study was conducted at Department of Medicine, D. Y. Patil hospital, Kolhapur. Total 103 study subjects were selected for study who were undergoing regular hemodialysis in current institution. Male study subjects were 53 (51.46%) while females were 50 (48.54%). Among study subjects 103 subjects, 57 (55.34%) in stage IV followed by 46 (44.66%) were in stage V. Out of 103 subjects, 46 (44.66%) were doing hemodialysis since last 1 to 3 years followed by 41 (39.81%) of subjects doing hemodialysis for previous 6 to 12 month. Conclusion: According to our findings, it can be concluded that patients with ESRD who receive hemodialysis may have a better pulmonary function after dialysis sessions, which is significant for FVC, FEV1, FEV1/ FVC ratio and PEFR.

Keywords: hemodialysis, pulmonary functions, end stage renal disease, FVC

INTRODUCTION

End Stage Renal Disease (ESRD) is the circumstance when kidney function is inadequate to bear life and there is then an essential need for either haemodialysis (HD), peritoneal dialysis (PD) or kidney transplantation, to cover for natural kidney function. [1] As CKD patients tend to suffer from many comorbidities but Non-infectious pulmonary complications are common in patients with long term chronic kidney disease.[2] The continuum of possible underlying pathologies is huge since end-stage kidney disease is a multifaceted syndrome capable of affecting virtually every organ system. [3] Since 1901 mention has been made of lung disease

occurring in the course of uremia, [4] which might be occurring primarily due to volume overload.[5] The buildup of toxins, liquids, and electrolytes due to the declined glomerular filtration will lead to the uremic syndrome or worse patient's death if it is not treated effectively with renal replacement therapies such as hemodialysis, peritoneal dialysis, or kidney transplantation.[6] The intermittent hemodialysis (IHD) has been a useful renal replacement therapy for critically ill patients.[7] Pulmonary dysfunction in end-stage kidney disease has been seen as a straight effect of circulating uremic toxins or a secondary effect of volume overload, anemia, immune suppression, premature airway closure, ventilation-perfusion mismatching, severe mechanical loading, gas transfer defects, malnutrition, electrolyte disorders, and/or acid/base imbalances.[8-11] The muscles accountable for decent respiratory function, like diaphragm and intercostal, might display reductions in muscle strength and stamina properties consequential from uremic myopathy.[12] The declined immune response and alteration in fluid homeostasis in ESRD can present with a plethora of respiratory complications, which include pulmonary edema, fibrinouspleuritis, pulmonary calcification, increased predisposition to tuberculosis, obstructive sleep apnea, and a rarer entity, urinothorax. [13-15] Numerous changes in pulmonary function, including restriction, obstruction and impaired diffusion capacity, have been described in this patient population.[16] These pulmonary dysfunctions may be caused directly by an underlying primary pulmonary disease or the high incidence of smoking, but the influence of uremia and the effects of dialysis treatment with the artificial kidney are not well characterized. [17] It was reported that chronic respiratory diseases were responsible for 10·9% (95% UI 10·0–12·0) of the total deaths and 6·4% (5·8–7·0) of the total DALYs in India in 2016. [18]Hence, the present study was conductedto study effect of Hemodialysis on pulmonary function in patients with End stage renal disease.

MATERIALS AND METHODS

The present study was conducted at Department of Medicine, D. Y. Patil Hospital, Kolhapur, Maharashtra. A prospective observational study design was used for the study. All End Stage Renal Disease study subjects undergoing regular hemodialysis in D. Y. Patil hospital IPD were included in the study. We used purposive sampling to select a total population of study participants from dialysis units. This is where by the entire population that meets the criteria is included in the research being conducted. The number of CKD patients on hemodialysis were limited due to outbreak of COVID - 19; hence we used the total population. We sampled all the hemodialysis patients from four selected units that met the inclusion and exclusion criteria.

Following criteria's were selected for choosing study subjects.

INCLUSION CRITERIA

1. Diagnosed CKD patients based on KDIGO guidelines
2. Age >18 years
3. Patient undergoing hemodialysis

EXCLUSION CRITERIA

A. Patient with Chronic obstructive pulmonary disease
B. H/O Asthma
C. Patient with Malignancy
D. Recent smoker
E. Patients with respiratory disease onset before the diagnosis of CKD
F. Known cardiovascular diseases

SAMPLE SIZE

Total 103 study subjects were selected from population. Present study was conducted from 2020 to 2021.

STUDY MEASURE

A standard form was used to collect information regarding: age, sex, cause of end-stage renal disease, and duration and frequency of hemodialysis from each patient. BMI was calculated using patient's height and weight calibrated upto 0.01 units of measurement. It was calculated and classified according to guidelines of WHO. Kidney function parameters were assessed with help of serum, before and after hemodialysis.

HEMODIALYSIS

All Hemodialysis sessions were performed with a volumetrically controlled ultrafiltration machine, first-use modified cellulose dialyzer membranes, and bicarbonate dialysate.

Dialysis was done using Fresenius 4008B dialysis machines (Fresenius Medical Care AG, Bad Homburg, Germany) which were kept on a strict maintenance regime. The water was treated by a reverse-osmosis de-ionizing system. The filters were single-use polysulphonehighflux Dialyzers. The mean Kt/V was 1.38. Patients with shorter dialysis sessions, reduced ultrafiltration, and fluid infusion were approached at another dialysis session.

Patients with no contraindications for anticoagulation received systemic unfractionated heparin; otherwise, the circuit was flushed with saline each 20 minutes. No alterations were made in the patients' hemodialysis prescriptions or dietary instructions during the study period. Dialyzer surface area corresponding to 60% of BSA was selected for each patient. Dialysate flow rate was 500 ml/min and blood flow rates were targeted as per the patient requirement. Dialyzer re-use was uniformly performed using manual methods.

RESPIRATORY FUNCTION

The patients were evaluated in terms of pulmonary function with the help of spirometry. Spirometry assessments of forced vital capacity (FVC), forced expiratory volume in the first second (FEV1) and peak expiratory flow rate (PEFR) were obtained with flow accuracy ±5% and volume accuracy ±3%. Predicted normal values were calculated using the formulas by Crapo et al [31] and expressed as FEV1, FVC and PEFR. At least three reproducible tests were carried out for each measurement and the highest was recorded. Spirometry was performed using a Pony Graphics spirometer (Cosmed, Rome, Italy) and in accordance with the standards set forth by the American Thoracic Society. [7] All spirometry tests were done by the same person and in the mornings. The parameters measured before and after dialysis were forced expiratory volume in the first second (FEV1), forced vital capacity (FVC), the FEV1/FVC ratio and peak expiratory flow rate (PEFR).

STATISTICAL ANALYSIS

Data was entered in excel and analyzed using statistical software Epi Info 7.1.4. Descriptive statistics (percentage, mean, standard deviation, range) were used to summarize baseline characteristics of the study subjects. An association between two continuous variables was analyzed by using paired t test. p value < 0.05 was considered to be statistically significant.

RESULTS

A prospective observational study was conducted at Department of Medicine, D. Y. Patil hospital, Kolhapur. Total 103 study subjects were selected for study who were undergoing regular hemodialysis in current institution.

Table 1: Distribution of study subjects according to sex

Sr. No	Sex	Frequency	Percentages
1	Male	53	51.46
2	Female	50	48.54
Total		103	100

Table 1 shows distribution of study subjects according to sex. Nearly equal distribution of sex was observed. Male study subjects were 53 (51.46%) while females were 50 (48.54%).

Table 2: Distribution of study subjects according to chronic kidney disease stages

Sr. No	CKD stage	Frequency	Percentages
1	IV	57	55.34
2	V	46	44.66
Total		103	100.00

Table 2 shows chronic kidney disease stages, among study subjects 103 subjects, 57 (55.34%) in stage IV followed by 46 (44.66%) were in stage V.

Table 3: Distribution of study subjects according to duration of hemodialysis

Sr. No	Duration	Frequency	Percentages
1	< 6 mo	11	10.68
2	6 - 12 mo	41	39.81
3	1 yr - 3 yrs	46	44.66
4	> 3 yrs	5	4.85
Total		103	100.00

Table 3 shows distribution of study subjects according to duration of hemodialysis. Out of 103 subjects, 46 (44.66%) were doing hemodialysis since last 1 to 3 years followed by 41 (39.81%) of subjects doing hemodialysis for previous 6 to 12 month.

Table 4: Before and after hemodialysis effects on respiratory function parameters among study subjects.

Sr. No	Investigation	Before Hemodialysis		After Hemodialysis		p value
		Mean	± S.D.	Mean	± S.D.	
1	FVC	53.04	13.46	56.91	13.17	0.03
2	FEV1	52.54	14.16	56.83	12.89	0.02
3	FEV1/FVC	98.72	15.86	102.98	14.79	0.04
4	PEFR	59.22	12.54	63.95	12.07	0.006

Table 4 shows before and after hemodialysis effects on respiratory function parameters among study subjects. Overall increase in respiratory function tests was observed. Mean FVC before hemodialysis was 53.04 L which was increased to 56.91 L. Mean FEV1 before hemodialysis was 52.54 L which was increased to 56.83 L. Mean FEV1/FVC before hemodialysis was 98.72 L which was increased to 102.98 L. Mean PEFR before hemodialysis was 59.22 L which was increased to 63.95 L. A statistical significant association was found with hemodialysis with improvement in FVC, FEV1, FEV1/FVC and PEFR values.

Table 5: Before and after hemodialysis effects on kidney function parameters among study subjects.

Sr. No	Investigation	Before Hemodialysis		After Hemodialysis		p value
		Mean	± S.D.	Mean	± S.D.	
1	Urea (mg/dL)	141.65	10.60	121.78	8.68	0.004
2	Creatinine	10.0	2.90	7.9	2.2	0.001

	(mg/dL)					

Table 5 shows before and after hemodialysis effects on kidney function parameters among study subjects. Overall improvement in kidney function tests was observed. Mean urea before hemodialysis was 141.65 mg/dl which was improved to 121.78 mg/dl. Mean creatinine before hemodialysis was 10.0 mg/dl which was improved to 7.9 mg/dl. A statistical significant association was found with hemodialysis with improvement in urea and creatinine values.

Fig 1:

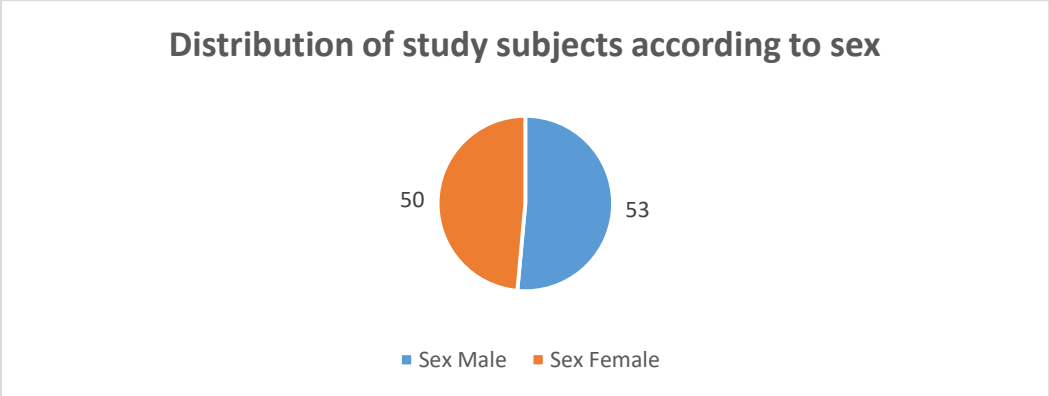


Fig 2:

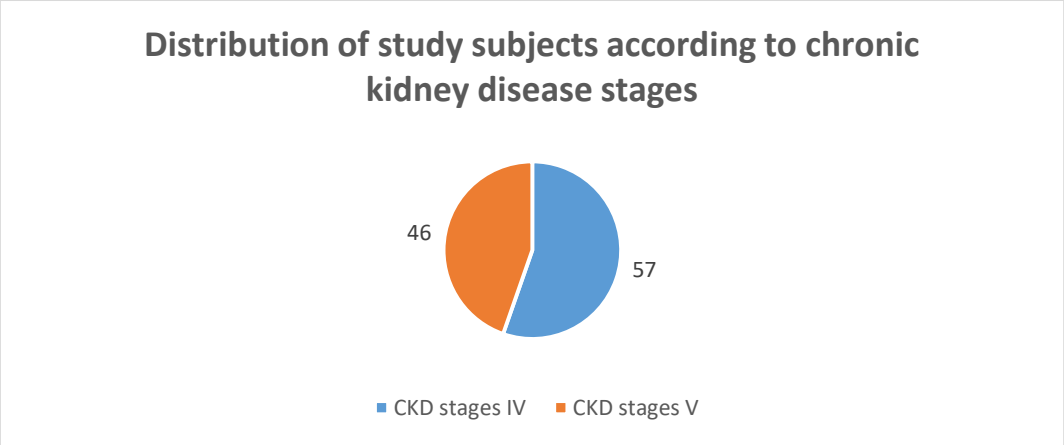
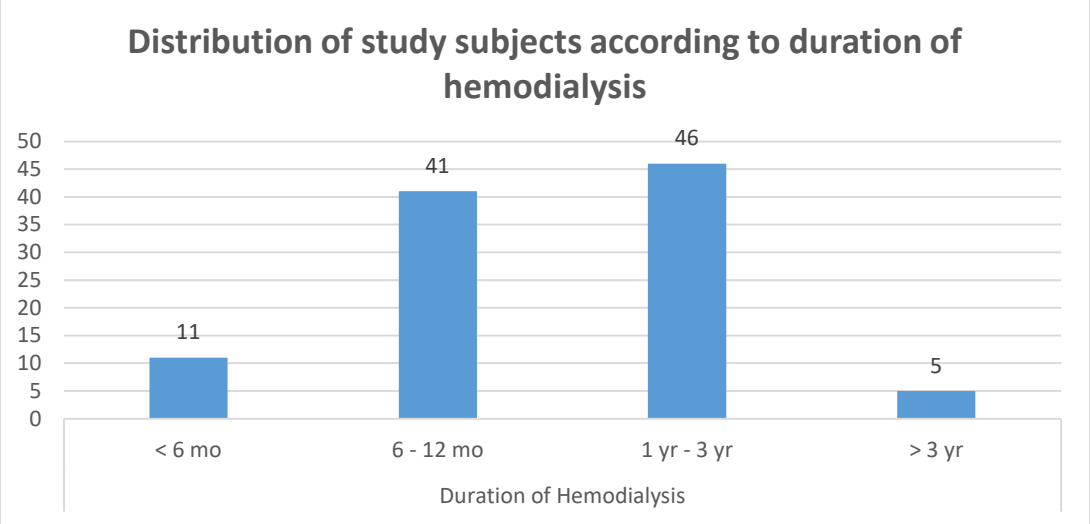


Fig 3:



DISCUSSION

Patients on hemodialysis are exposed to continuous pulmonary insults of multifactorial origin. A prospective observational study was conducted at Department of Medicine, D. Y. Patil hospital, Pune. Total 103 study subjects were selected for study who were undergoing regular hemodialysis in current institution.Present study demonstrated nearly equal distribution of sex. Male study subjects were 53 (51.46%) while females were 50 (48.54%). Mohanty et al found out similar findings.[19] Ravi Kumar P et al found slightly higher female study subjects 235 (55.72%).[20]Shaik et al found out that 178 (71.2%) were male cases.[13] Sharma A et al found 62% of male cases.[1] Lim H et al reported that 44% male CKD patients.[21]

Among study subjects 205 subjects, 91(44.39%) were in stage v followed by 57 (27.80%) in stage IV. Ravi Kumar P et al found out only one (1.00%) case of stage V.[20] Rajapurkar et al found out that 25.9% of cases were in stage IV and 48.1% in stage V.[22] Sathayan S et al observed that an overwhelming majority of the patients in the study presented in stage V CKD 264 (79.2%).[8]

Out of 205 subjects, 91(44.39%) were doing hemodialysis, since last 1 to 3 years followed by 81(39.51%) of subjects doing hemodialysis for previous 6 to 12 month. Sharma A et al reported that 45 (90%) patients had been on hemodialysis for six months to three years and only 10% had been on hemodialysis for less than six months.[1]

Majority of study subjects 119(58.51%) of subjects were doing hemodialysis twice a week, followed by 63(30.73%). Shaik et al found out that cases received hemodialysis either two times per week (85.2%) or three times per week (14.8%).[13] Sharma A et al reported that majority (58%) of the study patients (62% of the males and 50% of the females) were undergoing HD twice a week, while 30% of all the patients (31% of the males and 28% of the females) were undergoing HD three times a week. [1]Mukakarangwa MC et al observed that majority of cases 26 (64%) were having hemodialysis three days a week. [23]

RESPIRATORY FUNCTIONS

Overall increase in respiratory function tests was observed.

FVC

Mean FVC before hemodialysis was 53.04 L which was increased to 56.91 L. Sharma A et al reported that mean FVC of the study patients was 45.8 ± 24.9% before hemodialysis, which was significantly increased to 51.1 ± 23.4. [1] Lang et al also had similar observations. [17] Kovelis D et al reported FVC prior to hemodialysis 81 (75-90), which was improved to 86 (77-95).[24] Yilmaz S et al reported that pre-dialysis FVC was 2.61 $\pm$ 1.22 which was improved to 2.80 $\pm$ 1.12. [25]Karacan O et al reported that FVC pre-dialysis was 83.9 $\pm$ 13.1, which was improved to 83.2 $\pm$ 10.5. [25] Anees M et al reported that FVC pre-dialysis was 2.00 $\pm$ 0.89, which was found to be 2.00 $\pm$ 0.96 post dialysis.[26]Navari K et al reported that before dialysis, FVC was 85.2, which was improved to 88.1.[27]

FEV1

Mean FEV1 before hemodialysis was 52.54 L which was increased to 56.83 L. Sharma A et al reported that mean FEV1 of the study patients was 43.5 ± 25.9%, which was significantly increased to 49.3 ± 25.5%.[1] Lang et al also had similar observations. [17] Kovelis D et al observed that FEV 1 prior to hemodialysis was 83 (74-95), which was increased to 87 (77-96). [24]Yilmaz S et al reported that pre-dialysis FEV1 was 2.08 $\pm$ 0.99 which was improved to 2.20 $\pm$ 0.93. [25] Karacan O et al reported that FEV1 pre-dialysis was 86.0 $\pm$ 13.8, which was improved to 87.6 $\pm$ 11.7. [28]Anees M et al reported that FEV1 pre-dialysis was 1.59 $\pm$ 0.68,

which was found to be 1.53 ± 0.73 post dialysis.[26] Navari K et al reported that before dialysis, FEV1 was 88.8, which was improved to 91.9. [29]

FEV1/FVC

Mean FEV1/FVC before hemodialysis was 98.72 L which was increased to 102.98 L. Sharma A et al reported that mean FEV1/FVC% of the study patients was 97.8 ± 20.8%, which was significantly increased to 99.3 ± 20.1%.[1] Lang et al also had similar observations.[17] Kovelis D et al reported that FEV1/FVC was prior to hemodialysis 89 (81-100) which was decreased to 82 (81-102). [24] Yilmaz S et al reported that pre-dialysis FEV1/FVC was 0.79 ± 0.08 which was improved to 0.78 ± 0.07. [25] Anees M et al reported that FEV1/FVC pre-dialysis was 81.46 ± 11.71, which was found to be 78.95 ± 14.33 post dialysis.[26] Navari K et al reported that before dialysis, FEV1/FVC was 104.0, which was unchanged to 104.0.[29]

PEFR

Mean PEFR before hemodialysis was 59.22 L which was increased to 63.95 L. Mean PEFR of the study patients was 43.8 ± 30.7%, which was significantly increased to 49.1 ± 29.9%. Lang et al also had similar observations. [17] Yilmaz S et al reported that pre-dialysis PEFR was 4.53 ± 1.14 which was improved to 4.58 ± 1.92. [25]

KIDNEY FUNCTION

Overall improvement in kidney function tests was observed. Mean urea before hemodialysis was 141.65 mg/dl which was improved to 121.78 mg/dl. Mean creatinine before hemodialysis was 10.0 mg/dl which was improved to 7.9 mg/dl. Sharma A et al found out similar improvement in kidney function.[1] Steinhorst RC et al observed that after 40 hemodialysis sessions significant kidney function improvement. [7]RahgoshaI R et al reported that urea level did not significantly improved with hemodialysis. [30]

CONCLUSION

Pulmonary function abnormalities were common among our study patients, but were significantly ameliorated after HD. According to our findings, it can be concluded that patients with ESRD who receive hemodialysis may have a better pulmonary function after dialysis sessions, which is significant for FVC, FEV1, FEV1/ FVC ratio and PEFR.

REFERENCES

1. Sharma A, Sharma A, Gahlot S, Prasher PK. A study of pulmonary function in end-stage renal disease patients on hemodialysis: A cross-sectional study. Sao Paulo Med J. 2017;135(6):568–72.
2. Mukai H, Ming P, Lindholm B, Heimbürger O, Barany P, Anderstam B, et al. Restrictive lung disorder is common in patients with kidney failure and associates with protein-energy wasting, inflammation and cardiovascular disease. PLoS One. 2018;13(4):1–13.
3. Plesner LL, Warming PE, Nielsen TL, Dalsgaard M, Schou M, Høst U, et al. Chronic obstructive pulmonary disease in patients with end-stage kidney disease on hemodialysis. Hemodial Int. 2016;20(1):68–77.
4. Zarday Z, Benjamin JJ, Koerner SK, Veith FJ, Gliedman ML, Soberman R. Effects of hemodialysis and renal transplantation on pulmonary function. Chest [Internet]. 1973;63(4):532–5. Available from: http://dx.doi.org/10.1378/chest.63.4.532
5. Srithongkul T, Lyons OD, Faratro R, Chan CT. Changes in pulmonary restrictive parameters by intensive home hemodialysis: A case report. BMC Nephrol. 2020;21(1):1–4.
6. Momeni M, Shahraki E. Early Effects of Hemodialysis on Pulmonary Function in Patients with End-Stage Renal Disease. Zahedan J Res Med Sci. 2020;22(3):1–5.

7. Steinhorst RC, Vieira JM, Abdulkader RCRM. Acute effects of intermittent hemodialysis and sustained low-efficiency hemodialysis (SLED) on the pulmonary function of patients under mechanical ventilation. Ren Fail. 2007;29(3):341–5.
8. Sathyan S, George S, Vijayan P, M. J. Clinical and epidemiological profile of chronic kidney disease patients in a tertiary care referral centre in South India. Int J Community Med Public Heal. 2016;3(12):3487–92.
9. Safa J, Noshad H, Ansarin K, Nikzad A, Saleh P, Ranjbar A. Effect of hemodialysis on pulmonary function tests and plasma endothelin levels. Saudi J Kidney Dis Transpl. 2014;25(4):781–7.
10. Palamidas AF, Gennimata SA, Karakontaki F, Kaltsakas G, Papantoniou I, Koutsoukou A, et al. Impact of hemodialysis on dyspnea and lung function in end stage kidney disease patients. Biomed Res Int. 2014;2014.
11. Alhamad EH, Al-Ghonaim M, Alfaleh HF, Cal JP, Said N. Pulmonary hypertension in end-stage renal disease and post renal transplantation patients. J Thorac Dis. 2014;6(6):606–16.
12. Abdalla ME, AbdElgawad M, Alnahal A. Evaluation of pulmonary function in renal transplant recipients and chronic renal failure patients undergoing maintenance hemodialysis. Egypt J Chest Dis Tuberc [Internet]. 2013;62(1):145–50. Available from: http://dx.doi.org/10.1016/j.ejcdt.2013.04.012
13. Shaik L, Thotamgari SR, Kowtha P, Ranjha S, Shah RN, Kaur P, et al. A Spectrum of Pulmonary Complications Occurring in End-Stage Renal Disease Patients on Maintenance Hemodialysis. Cureus. 2021;13(6):6–11.
14. Yuenyongchaiwat K, Vasinsarunkul P, Phongsukree P, Chaturattanachaiyaporn K, Tritanon O. Duration of hemodialysis associated with cardio-respiratory dysfunction and breathlessness: a multicenter study. PeerJ. 2020;8.
15. El-Gamasy MA. Study of some pulmonary function tests in Egyptian children with end-stage renal disease under regular hemodialysis in correlation with dialysis duration. Saudi J Kidney Dis Transpl. 2019;30(1):119–28.
16. Mukai H, Ming P, Lindholm B, Heimbürger O, Barany P, Stenvinkel P, et al. Lung dysfunction and mortality in patients with chronic kidney disease. Kidney Blood Press Res. 2018;43(2):522–35.
17. Lang SM, Becker A, Fischer R, Huber RM, Schiffl H. Acute effects of hemodialysis on lung function in patients with end-stage renal disease. Wien KlinWochenschr. 2006;118(3–4):108–13.
18. Salvi S, Kumar GA, Dhaliwal RS, Paulson K, Agrawal A, Koul PA, et al. The burden of chronic respiratory diseases and their heterogeneity across the states of India: the Global Burden of Disease Study 1990–2016. Lancet Glob Heal. 2018;6(12):e1363–74.
19. Mohanty NK, Sahoo KC, Pati S, Sahu AK, Mohanty R. Prevalence of chronic kidney disease in cuttack district of Odisha, India. Int J Environ Res Public Health. 2020;17(2):5–12.
20. Kumar P R, Dongre A, Muruganandham R, Deshmukh P, Rajagovindan D. Prevalence of Chronic Kidney Disease and Its Determinants in Rural Pondicherry, India-A Community Based Cross-Sectional Study. Open UrolNephrol J. 2019;12(1):14–22.
21. Lim H Il, Jun SJ, Lee SW. Glomerular hyperfiltration may be a novel risk factor of restrictive spirometry pattern: Analysis of the Korea National health and nutrition Examination Survey (KNHANES) 2009-2015. PLoS One. 2019;14(9):1–14.
22. Rajapurkar MM, John GT, Kirpalani AL, Abraham G, Agarwal SK, Almeida AF, et al. What do we know about chronic kidney disease in India: First report of the Indian CKD registry. BMC Nephrol. 2012;13(1).
23. Mukakarangwa MC, Chironda G, Bhengu B, Katende G. Adherence to Hemodialysis and Associated Factors among End Stage Renal Disease Patients at Selected Nephrology Units in Rwanda: A Descriptive Cross-Sectional Study. Nurs Res Pract. 2018;2018:1–8.

24. Kovelis D, Pitta F, Probst VS, Peres CPA, Delfino VDA, Mocelin AJ, et al. Pulmonary function and respiratory muscle strength in chronic renal failure patients on hemodialysis. J bras pneumol. 2008;34(11):907–12.
25. Yilmaz S, Yildirim Y, Yilmaz Z, Kara AV, Taylan M, Demir M, et al. Pulmonary function in patients with end-stage renal disease: Effects of hemodialysis and fluid overload. Med SciMonit. 2016;22:2779–84.
26. Anees M, UzZamanAdhami S, Aamer M, Shahid I. Pulmonary functions in patients with end stage renal disease and their effect after hemodialysis. J Coll Physicians Surg Pakistan. 2021;31(2):144–9.
27. Navari K, Farshidi H, Pour-Reza-Gholi F, Nafar M, Zand S, Sohrab Pour H, et al. Spirometry parameters in patients undergoing hemodialysis with bicarbonate and acetate dialysates. Iran J Kidney Dis. 2008;2(3):149–53.
28. Karacan Ö, Tutal E, Uyar M, Eyüboğlu FÖ, Sezer S, Özdemir FN. Pulmonary function in uremic patients on long-term hemodialysis. Ren Fail. 2004;26(3):273–8.
29. Navari K, Farshidi H, Pour-Reza-Gholi F, Nafar M, Zand S, Sohrab Pour H, et al. Spirometry parameters in patients undergoing hemodialysis with bicarbonate and acetate dialysates. Iran J Kidney Dis. 2008;2(3):149–53.
30. Rahgoshai R, Rahgoshai R, Khosraviani A, Nasiri AA, Solouki M. Acute effects of hemodialysis on pulmonary function in patients with end-stage renal disease. Iran J Kidney Dis. 2010;4(3):214–7.