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Near-Infrared Spectroscopic Estimation of Urea Concentration for Determining Appropriate Duration of Hemodialysis Treatment

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Abstract— **In conventional dialysis treatment, the evaluation of treatment effects is based on pre- and post-treatment blood tests. Therefore, if the effect can be evaluated in real time by point of care testing (POCT) device, it will be possible to provide more suitable treatment for each patient. In this study, we estimated urea concentration in mixed solution of urea, uric acid, and creatinine by near-infrared spectroscopy. Assuming a POCT device using an LED light source, the analysis was performed using ten wavelengths equivalent to commercially available LEDs. Estimation accuracy was assessed by standard error of prediction (SEP) and correlation coefficient between actual and estimated concentration. As a result, it is possible to estimate urea concentration with high accuracy when using an optical path length of 0.25 mm or more and using 6 to 7 wavelengths.**

Clinical Relevance— This contributes to the construction of a real-time evaluation system for dialysis effect.

I. INTRODUCTION

There are more than 330,000 chronic dialysis patients in Japan [1], and most of them are treated in hospitals about three times a week. The evaluation of the treatment is performed only about once a month based on blood urea (urea reduction ratio and Kt/V), and the effect of each treatment three times a week has not been assessed. There is a possibility that urea and other wastes are not sufficiently removed or that the patient is treated longer than necessary. Therefore, we focused on the estimation of urea concentration in dialysis wastewater for determining appropriate duration of hemodialysis treatment. The ultimate goal is to build a near-infrared spectroscopic system as a POCT device that can estimate urea in dialysis wastewater with high accuracy. In this study, the main estimation target was urea, and the measurement sample was a mixed aqueous solution with uric acid and creatinine as interferents. We optically estimated urea concentration in the solution and tried to estimate it at a smaller number of wavelengths using statistical methods.

II. MATERIALS AND METHODS

In this experiment, samples were prepared by adding each powdered reagent to pure water. The concentrations of a total of 20 different samples are combinations of the following concentrations (urea: 10, 15, 20, 25, 30, UA: 0.7, 2.0, creatinine: 1.0, 4.0 mg/dl). Absorbance of each sample were measured in triplicate using an FT-IR spectrometer (Spectrum One, Perkin Elmer) with wavelength range of 750-2500 nm. We prepared flow-through cells with four different optical path lengths (0.5, 0.15, 0.25, 0.05 mm). Multiple linear regression analysis (MLR) with all combinations of 10 wavelengths (1023 sets) was carried out. Leave-one-out cross validation was used for all results.

III. RESULTS

Table 1 shows the results of correlation studies between the actual concentrations determined by the clinical laboratory methods, and those estimated by the MLR models obtained from NIRS. The number of wavelengths shown here represents the case where the SEP is the smallest among all combinations. As shown Table 1, it was confirmed that the SEP decreased with increasing optical path length, and a correlation coefficient (γ) of 0.9 or higher was shown for optical path lengths of 0.25 mm or longer.

Table 1 Results of correlation studies for estimated urea concentration in mixed aqueous solution.

Path length [mm]	Number of wavelegths	SEP [mg/dl]	γ
0.05	7	5.30	0.670
0.15	4	4.37	0.814
0.25	7	2.90	0.914
0.5	6	2.13	0.959

IV. DISCUSSION & CONCLUSION

With the goal of developing a POCT device, we estimated urea in mixed aqueous solution with UA and creatinine using ten wavelengths equivalent to commercially available LEDs. As a result, it was confirmed that the concentration of urea can be estimated with high accuracy by using several wavelengths corresponding to commercial LEDs, and a foothold was obtained for the construction of an optical system for dialysis wastewater.

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REFERENCES

[1] K. Nitta *et. al.,* "Annual dialysis data report for 2018, JSDT Renal Data Registry: survey methods, facility data, incidence, prevalence, and mortality", Renal Replacement Therapy, vol.6, Article number: 41, 2020.