Preliminary Examination for Colorimetry of Removed & Re-transfused Blood and Skin of Hemodialysis Patients

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ABSTRACT

Patients of the end-stage kidney disease ESKD being treated with the Blood Purification Method are growing worldwide. Taking note of the characteristic that hemodialysis makes accurate assessment of body water amount and moving blood pressure possible and so on, our study aims to explore causal relations between patients' blood and face color with their vital data. Focusing on the hemodialysis circuit apparatus of ESKD patients, this report deals with the measurement method and error of patients' blood color in removal and re-transfused blood tube, bloodline pressure pillow and air trap chamber. This report also deals with performance comparison with measuring instruments from accurate spectrophotometer to simplified sensor which is reasonably available to medical staff. Moreover, we acquire the blood color changes during the procedure of hemodialysis as the color difference, and indicate ways to a qualitative analysis of simultaneous relations between hemodialysis patients' skin color.

KEYWORDS: Blood Color, Hemodialysis, Colorimetry,

INTRODUCTION

Patients of the end-stage kidney disease (ESKD) being treated with the Blood Purification Method are growing worldwide. Japan has about 320,000 ESKD patients, which is the second largest number in the world behind USA). The number of ESKD patients per 100,000 people of Japan is the largest in the world). Therefore, enhancement of the treatment of ESKD is a top-class agenda and one of the national medical concerns in Japan.

79.5% of the ESKD patients in Japan are treated with Hemodialysis1). Usually, it takes 3 times of treatment in a week which lasts more than four hours to eliminate excessive water and electrolyte like Natrium out of patients' blood and to supplement necessary substances to survive. Hemodialysis treatment cannot be a perfect substitution for real natural kidney functions, so patients are required a longtime dietary treatment (regarding water, sodium, protein such as phosphorus, and so forth), medication, and attention to concomitant diseases. Moreover, as composition of body fluid changes rapidly thorough hemodialysis, further attentions about complication like blood pressure reductions and dialysis disequilibrium syndrome are required.

Medical staff especially nurses rely on their intuitive interpretation whether patients become ill based on observation of patients' face color. But the skin color change in worsening health condition is not scientifically quantified so there are variations of reaction depending on differences of medical staff' personal experience and past trainings. Also, regardless of the difference of medical staff' personal experience, it is a great merit for medical staff in patients care to be able to judge patients' conditions from their face color, and to be able to convey patients' information to other staff. It is also a great merit for patients to enjoy more stable medical environment.

SPECTRAL TRANSMITTANCE AND REFLECTANCE OF HUMAN BLOOD

The spectrophotometers CM-5 made by Konica Minolta was used for this experiment. The measurement diameter of CM-5 was 3mm, the light source was D65, mirror reflection was not included (SCE), and the viewing field was 10 degrees. The standard plastic containers with 50mm height and 30mm length and 10mm width were used in this experiment. These measurement conditions were same if other results were obtained by the use of CM-5 below in this paper.

Figure 1 shows spectral transmittance and reflectance of three subjects' blood. Average human blood is composed of 55% fluids and 45% cells (90% of the cells are red blood cells). We did not use anticoagulant in collecting blood, so as time passed, blood became serum and clot. The left result in Figure 1 shows spectral transmittance right after collecting blood. It shows significant individual differences. Sub 2 had well fed body and probably had symptom of Stress Erythrocytosis, therefore the blood might be high cell composition and high viscosity enough to cause very low spectral transmittance. The spectral transmittance of Sub 1 was the highest and probably had symptom of anemia with low red blood cell composition. Difference of spectral transmittance value of Sub 2 and Sub 3 was significant, but their spectrum waveform was similar. The second left result of Figure 1 shows spectral reflectance right after collecting blood (Sub3's result was absent). It also shows significant individual differences suggesting different compositions create different reflectance. The center result of Figure1 shows clot's reflectance after one day, with virtually no individual differences.

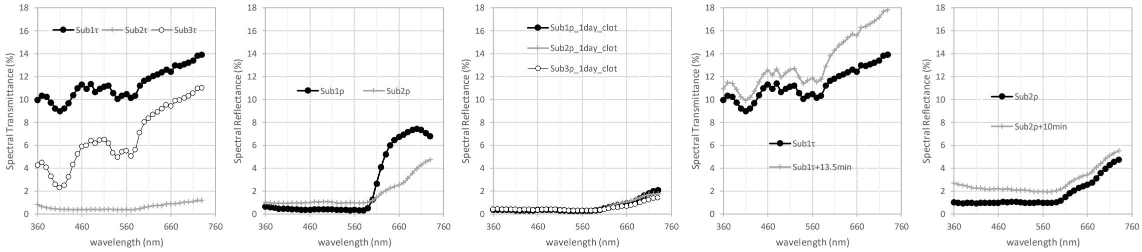


Figure 1: Blood Individual Differences of Spectral Transmittance and Reflectance (by CM-5).

Figure 1 also shows time change of blood. The transmittance measurement position of CM-5 was at the center of the container. As time passed, the separation of blood into serum and clot progressed, and the cells moved under the measurement position. That was why transmittance became higher after 13.5 minutes in the second right of Figure2. As the separation progressed, red-colored hemoglobin (Hb) moved under the bottom, which is the reflectance measurement position. Therefore, the reflectance became higher after 10 minutes in Figure1 right. Those results mean that it is better to measure the blood color and skin color of hemodialysis patients as simultaneously as possible when we explore the relations between blood and skin colors. If we should conduct blood color measurement later, it is necessary to use anticoagulant and centrifuge to prevent the separation into serum and clot.

SPECTRAL TRANSMITTANCE OF HEMODIALYSIS APPARATUS

In hemodialysis, it is necessary to remove blood in the amount of 150-300 ml/min. An internal shunt for hemodialysis achieves anastomosis between artery and vein of not-dominant forearm in order to lead arterial blood into vein, so the large amount of blood can be removed. By tapping from the internal shunt, the hemodialysis patients can remove blood, get rid of waste materials such as water and sodium, supply needed materials and then re-transfuse blood into vein. To check the situation of blood removal, medical staffs see a pillow on the side of blood pump is properly swollen. Previous studies [1] use this pillow as the point of blood color measurement. However, transparency is different by manufacturers or colors might be added, so it may not be the proper position for blood color measurement.

As our study pays attention to the variation of blood color in hemodialysis, we measured transmittance of three possible parts (large-bore tube, air trap chamber, and pillow) of hemodialysis apparatus made by three different manufacturers. In consideration of the transmission in tube shape is done twice, we took the square root of the measured value of transmittance. Figure 2 shows the results. All air trap chambers had similar transmittance, but pillows and large bore tubes had differences by manufacturers. Therefore, it can be said that when we examine the blood colors in numerous blood circuits, it does not mean much to use absolute values, but to use relative value such as color difference before and after the hemodialysis.

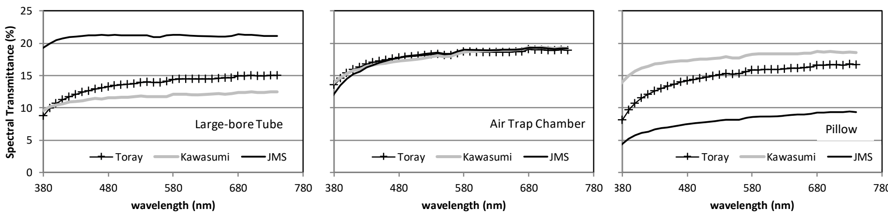
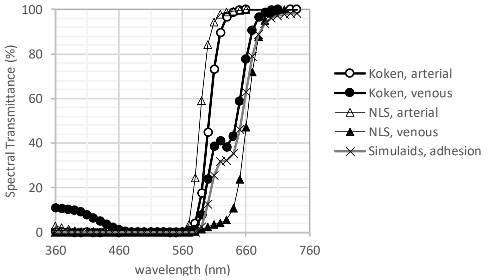


Figure 2: Spectral Transmittance of three parts of Hemodialysis Apparatus (by CM-5).

SELECTION OF EXPERIMENTAL MOCK BLOOD

As shown in Figure 1, real human blood has significant individual differences and time variation, so it is not realistic to use that for our examination. Instead, we used mock blood. In Japan, several manufacturers provide mock bloods. Their colors of mock bloods are close to the real arterial blood and venous blood, so they are widely used for first-aid training as a convenient replacement.

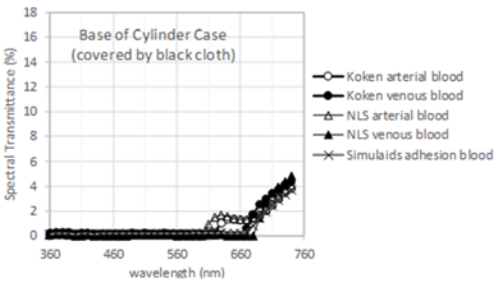
Figure 3 shows transmittance of mock bloods (5 kinds, 3 manufacturers). They had significant differences by manufacturers. Venous bloods had lower transmittance than arterial ones. Any of those samples did not include cell components, so they had higher transmittance than real human blood. Koken venous blood had similar spectral distribution to Simulaids adhesion blood which was made with adhesiveness to look like real blood with cell components. Both Koken venous blood and Simulaids adhesion blood had similar spectral distribution of real human blood, not simple logistic function.



Company	L*	a*	b*
Koken, arterial	44.57	75.72	76.55
Koken, venous	32.27	63.46	23.32
NLS, arterial	53.5	75.9	90.91
NLS, venous	12.43	40.84	21.3
Simulaids, adhesion	26.39	56.84	45.33

Figure 3: Spectral Transmittance of Mock Bloods (by CM-5).

The spectrophotometers CM-2600d made by Konica Minolta was used for spectral reflectance measurement. The measurement diameter of CM-2600d was 3mm, light source was D65, mirror reflection was not included (SCE) and viewing field was 10 degrees. Clear plastic cylinder cases for contained mock bloods were used in this experiment, which had 89% transmittance, 30mm diameter, 2mm thickness and 9mm height. We put 5ml mock bloods to the level of 8mm inner size in the cylinder case. The measurement device was put on a table upside down to measure the bottom of the cylinder case. The cylinder case was covered with black cloth in consideration of CM-5's condition. These measurement conditions were same if other results were obtained by the use of CM-2600d below in this paper. Figure 4 shows spectral reflectance results. Differences by manufacturers were smaller than transmittance results. Two venous blood (Koken and NLS) had similar spectral distribution to Simulaids adhesion blood and real human blood. In consideration of these two results and ease to adjust water amount in mock blood, we took Koken venous blood as our sample for BPM blood.



Company	L*	a*	b*
Koken, arterial	1.46	2.67	0.69
Koken, venous	1.51	-0.25	-0.19
NLS, arterial	1.82	7.7	2.58
NLS, venous	0.55	0.2	0.64
Simulaids, adhesion	1.88	0.21	0.41

Figure 4: Spectral Reflectance of Mock Bloods (by CM-2600d).

MAKING OF MOCK HEMODIALYSIS BLOOD

Normal adults have approximately 8% blood of entire body weight (weight 60kg person has 4-5L blood, it is about 4.4kg blood with specific weight of 1.054). Water removal amount of one hemodialysis session is ideally 3-5% of body weight (60kg body weight, 1.8-3.0kg). Taking sodium means need for more water. In other words, the weight of hemodialysis patient is determined by the sodium intake. Therefore, doctors instruct hemodialysis patients to practice diet regularly, to limit sodium(6g/day), potassium and phosphorus, and to take more protein. In the hemodialysis cycle which takes three times a week and each session about 4 hours, the longest gap is at the beginning of the week. Then the accumulated water and waste materials reach a maximum. At the time blood amount will be 12% higher, and blood constitute will be only 67% of the dry weight blood after water removal. We calculated the blood level variation by hour to make mock hemodialysis blood for this experiment; 0 hour=67%, 1 hour=73%, 2 hours=80%, 3 hours=89% and 4 hours=100%.

RESULTS OF MOCK HEMODIALYSIS BLOOD COLOR

The mock hemodialysis blood color was measured with cylinder case, air trap chamber and pillow of hemodialysis apparatus made by Kawasumi in Figure 3, and blood collection spitz tube. All the measurement surfaces were curved except cylinder case, so reproducibility had much to be desired. Figure 5 shows reflectance of mock hemodialysis blood. Pillow examined only one condition because of available number. There was no change among the different blood constitutes in the most stable result of cylinder case.

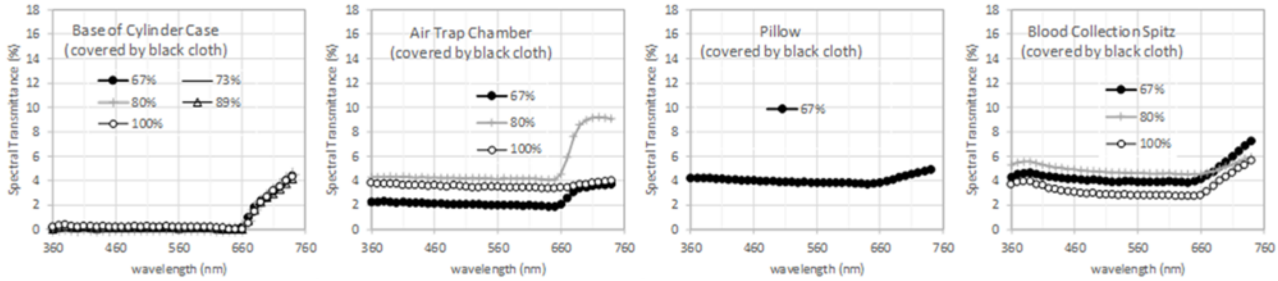


Figure 5: Spectral Reflectance of Mock Hemodialysis Bloods (by CM-2600d).

Figure 6 shows relations between blood constitutes and the color difference (delta E*ab) from 100% blood constitute of mock hemodialysis blood. The result showed no common tendency between blood constitute and color difference, which were not stable results of chamber and spitz. It is generally said that human can only recognize the color difference over space or time is delta E*ab >1.6. So, the color difference of the most stable result by cylinder case might be not detectable.

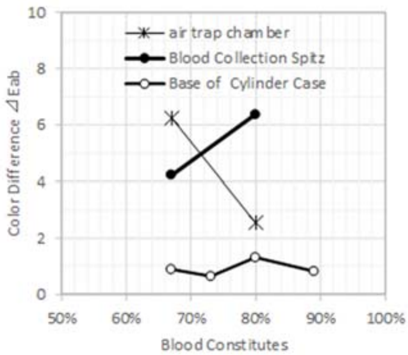


Figure 6: Relationship between blood constitutes and color difference from 100% blood constitute

PERFORMANCE COMPARISON OF COLORIMETERS

Today measurement devices of colors and lights are reasonably available in the market, therefore the medical staffs begin to start introducing them for daily nursing management. We compared the performance by two spectrophotometers under JIS specifications (CM-5 and CM-2600d) and two simple colorimeters with low prices (CR-13 made by Konica Minolta and the skin color sensor M228K-CLSM made by Moritex). Results showed although no significant differences between them when healthy skins were measured, skin color with high melanin pigment like sunburnt skin led to significant errors or they simply could not measure by simple colorimeters. M228K-CLSM could not properly measure except skin color. We suggest that medical facilities should use high precision types of measurement devices if they use nursing management based on skin color.

CONCLUSION

This report provided the problems regarding the blood color measurement in hemodialysis apparatus and blood collection spitz tube, and finds that no significant relations between blood constitute and blood color. However, the mock hemodialysis blood does not include red blood cells like real blood does, it is possible that actual measurement results of hemodialysis patients are different from ours. We will conduct further examination with measurement of actual patients' blood and skin color (face, back of hand, inside forearm).

ACKNOWLEDGEMENTS

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